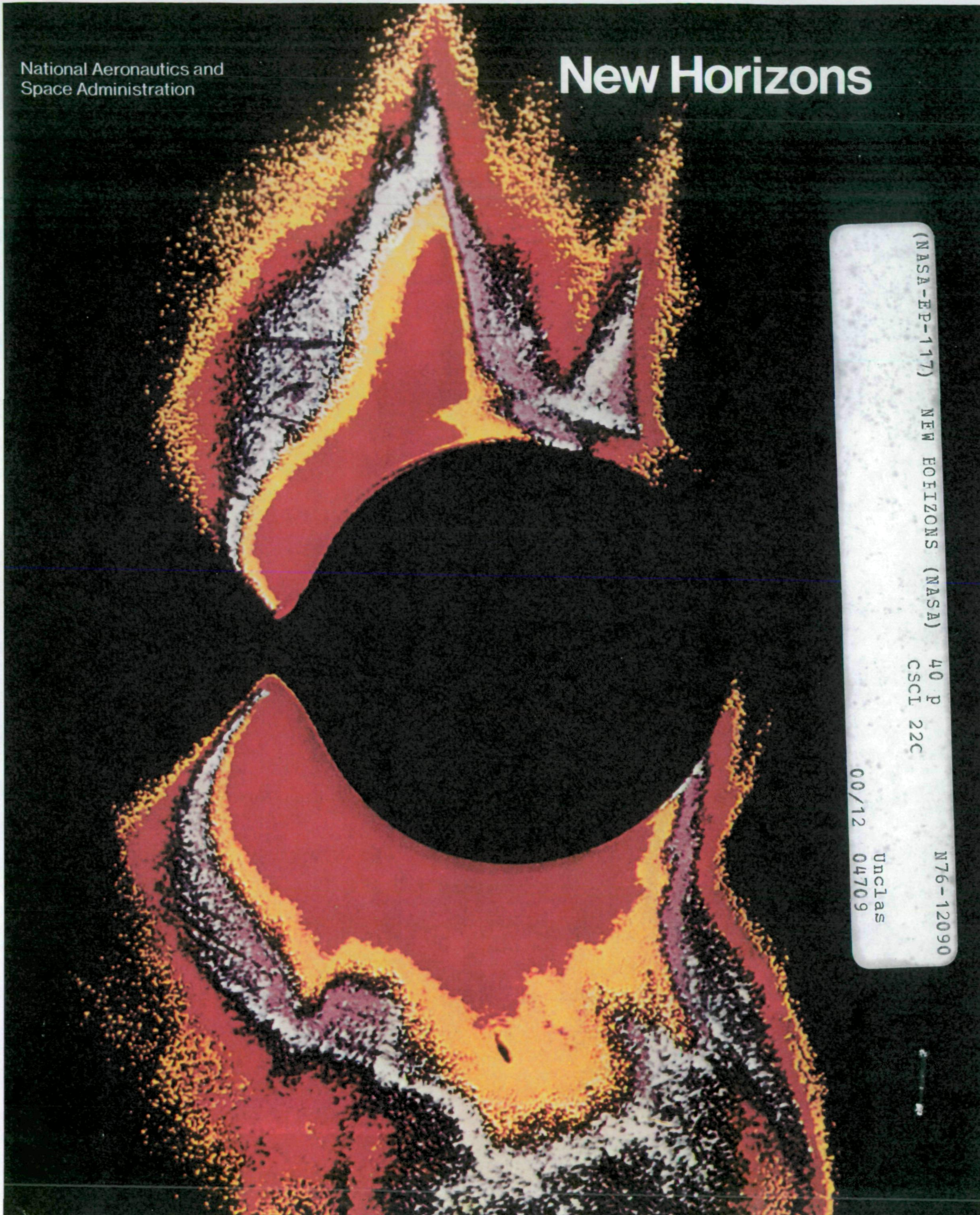
National Aeronautics and Space Administration

New Horizons



New Horizons

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Cover: A coronagraph on Skylab masked the Sun's disk, creating an artificial eclipse. Sun's hot outer atmosphere, or corona, color-coded to distinguish levels of brightness, reaches outward for millions of miles.

Opposite: This is what Chicago area looked like to an Earth resources camera on Skylab. Easy to pick out are such satellite cities as Aurora and Joliet, Illinois, and Gary and Hammond, Indiana.

President's Message

The manned space missions, including lunar landings and the long-duration Skylab missions, have demonstrated man's ability to explore other worlds as well as his own. Planetary investigations and solar discoveries are providing new insights into the origin and evolution of the Earth and the dynamics of the solar system.

The knowledge amassed through these expeditions has justified this Nation's commitment to probe the mysteries of space and has encouraged us to lift our eyes beyond our original goals.

The fruits of our national investment in space and aeronautics have stimulated the invention and manufacture of a host of new products and services for virtually every segment of society. These technical advances are being used to inventory crop yields and natural resources, to protect and improve the environment, to provide better health and medical care, to expand worldwide communications and weather forecasting, and to spur the development of safer, cleaner and more economical transportation systems.

Most important, our exploration of outer space has added another dimension to our outlook and made us more effective explorers of peace on Earth and goodwill among its peoples.

All Americans should be proud of what the space program has accomplished in the past—and excited by the prospect of future achievement and discovery.

Gerald R. Ford

President Ford holds container enclosing small segment of a unique crystal that was manufactured in space by one of the Skylab crews. Segment was presented by Dr. James C. Fletcher, *(left)*, NASA Administrator.

The mid-70's have arrived. And so has space. It is a good time to examine the path we have been travelling. It is a good time to assess NASA accomplishments and estimate the contributions of our research and our space exploration to the future of man.

We have, as never before, extended our powers of scientific observation and operation in space. The manned Skylab missions concluded early in 1974 with an 84-day flight that proved the utility of man in space. Besides qualifying man for long-duration space flight, the Skylab missions dramatized the feasibility of using large, permanent space stations for observing the Sun, the weather, Earth resources monitoring, and to produce, under zero gravity, materials that could not be duplicated on Earth.

With the unmanned spacecraft called Pioneer and Mariner, we completed incredibly long journeys to three planets—Venus, Mercury and Jupiter. We have reached out further and gained a better understanding of the Solar System. In so doing, we discover strong relationships between the processes which govern the evolution of these planets and the Earth. By looking out into the Universe, we understand our Earth a little better. We also strengthen our conviction that continued exploration of the Universe is necessary sustenance of the human spirit.

While scientists were finding great relevance and new information from the planetary missions, other spacecraft were developed and launched to serve man's direct and immediate needs. A very powerful communications satellite, Applications Technology Satellite-6, demonstrated that educational and medical consultation programs could be transmitted via low-cost receivers to overcome isolation and bring the most advanced services to persons in remote places.

Satellites launched by NASA have shown how reliable and productive space sentinels can be in reporting on weather and Earth resources. Space technology has provided the means for warning against the great weather forces which destroy life and property. Commercial use of domestic communications satellites has arrived.

The recent months illustrate the extent to which space activities have matured and come of age. Emphasis shifts more and more to applying space technology to serve human needs. The same holds true for NASA aeronautical research.

The years spent in developing a space and aeronautical research capability have provided NASA with a basis for contributing importantly to the solution of some of the nation's most pressing problems. Nowhere is this attribute more evident than in the field of aeronautics, where NASA's traditions of service (with its predecessor agency) go back 60 years.

Increasingly crowded air lanes, jet engine noise, steadily rising aviation costs, growing concern over fuel shortages and stronger foreign aircraft competition are some of the challenges that NASA programs are designed to meet. America's international leadership in developing civil and military aircraft has paid off handsomely on the plus side of the balance-of-payments ledger and in providing domestic employment. To lose this pre-eminence would place an intolerable burden on the nation's economy to say nothing of our air defense capabilities.

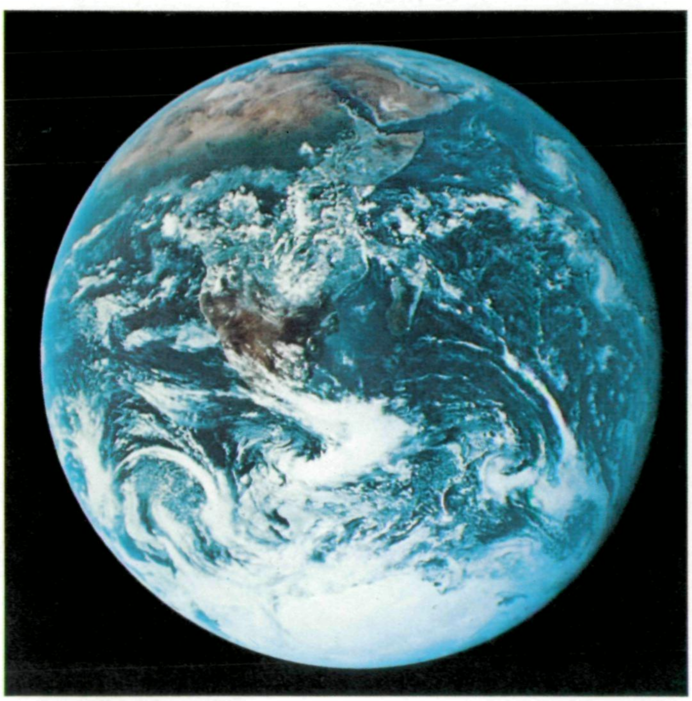
While much of NASA's total effort is helping to maintain and enhance U.S. world leadership in aviation, no opportunity is lost to focus technology on the solution, or easing, of such problems as airport neighborhood noise levels, objectionable engine emissions, air traffic congestion, flight safety, and fuel-conserving systems and techniques. The combined application of all the technologies that NASA is working on could lead to greatly improved efficiency of aircraft on operations, resulting in very significant savings of fossil fuel during the next 10 to 15 years.

In many fields—medicine, business, industry, education—space technology and aeronautical technology have provided new devices, processes, products and information of benefit to man. The flow and transfer of this technology is not incidental or accidental. It is the product of a conscious, determined effort to wring the most benefit for all out of every dollar spent on NASA research.

We are confident that NASA's achievements have established space exploration as a keystone in humanity's continued quest for new knowledge and better life on this planet.

James C Fletcher

Dividends from Space



It is somewhat of a paradox that the greatest discovery of the Space Age is the planet Earth. By moving out into space we have been able to view our world from a new perspective. We have seen its oneness and its beauty, its fragility and its limitations. And we are alarmed. For this blue oasis in the void which supports our human existence is indeed finite and incapable of sustaining indefinitely twentieth-century man's voracious appetite.

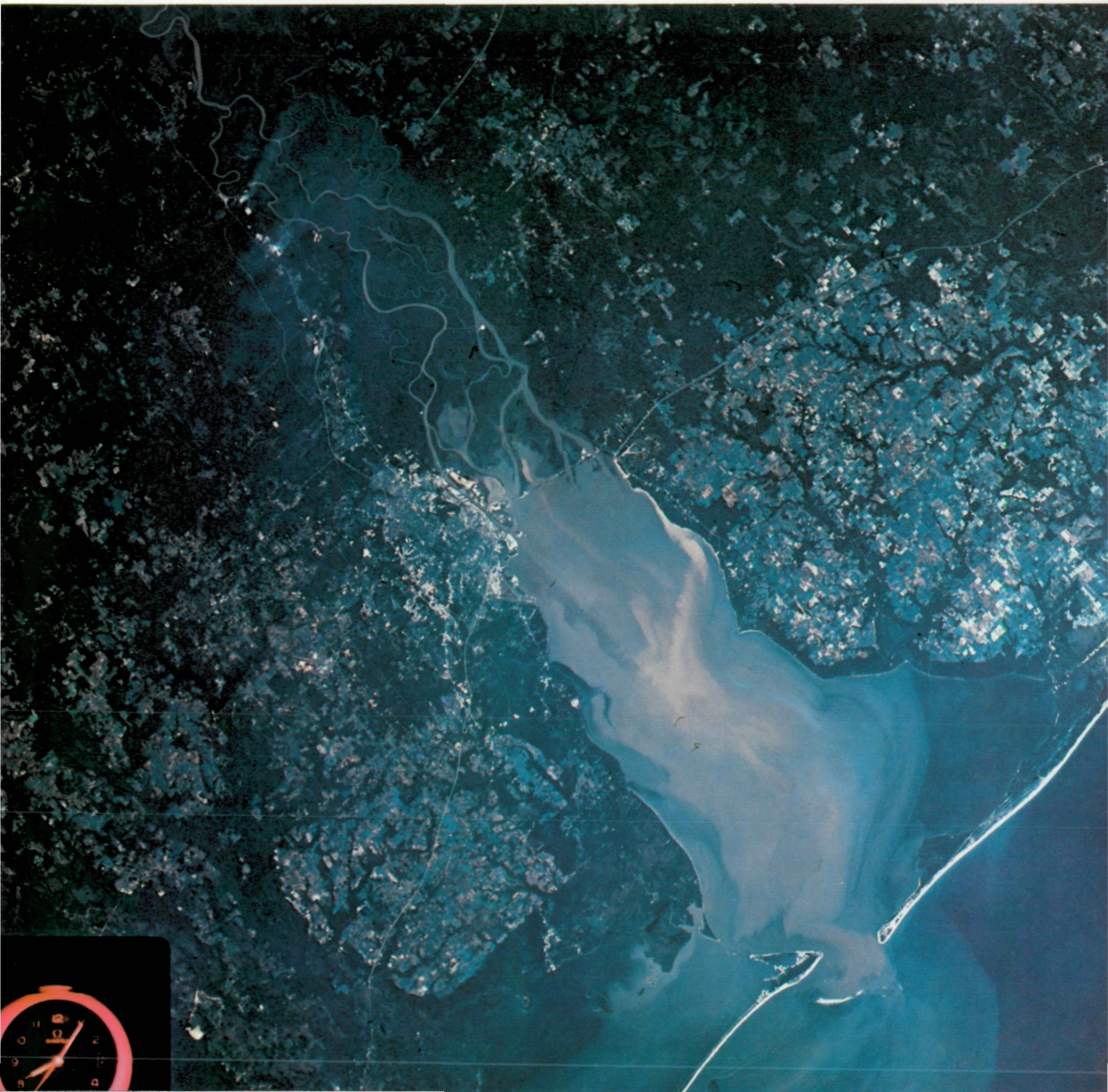
Fortunately, the technology that has opened our eyes and minds to the realities of the future also has given us the tools to meet the awesome challenges that lie ahead. Today, we are demonstrating that space technology and systems can be used effectively not only to preserve and manage Earth's precious resources and environment and to exploit its hidden riches, but also to enhance the quality of life for all its inhabitants.

The National Aeronautics and Space Administration continues to move aggressively towards these goals. Applications satellites launched by NASA have demonstrated an unmatched capability in crop surveillance, land-use surveys, weather forecasting, education, communications, pollution monitoring, navigation and the search for new mineral and energy sources.

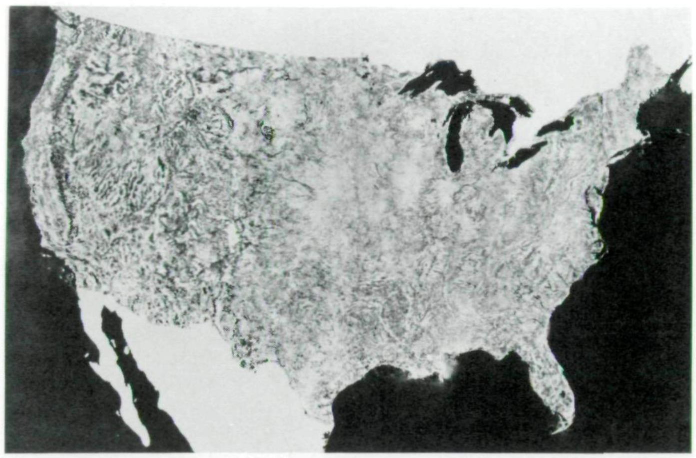
The Land

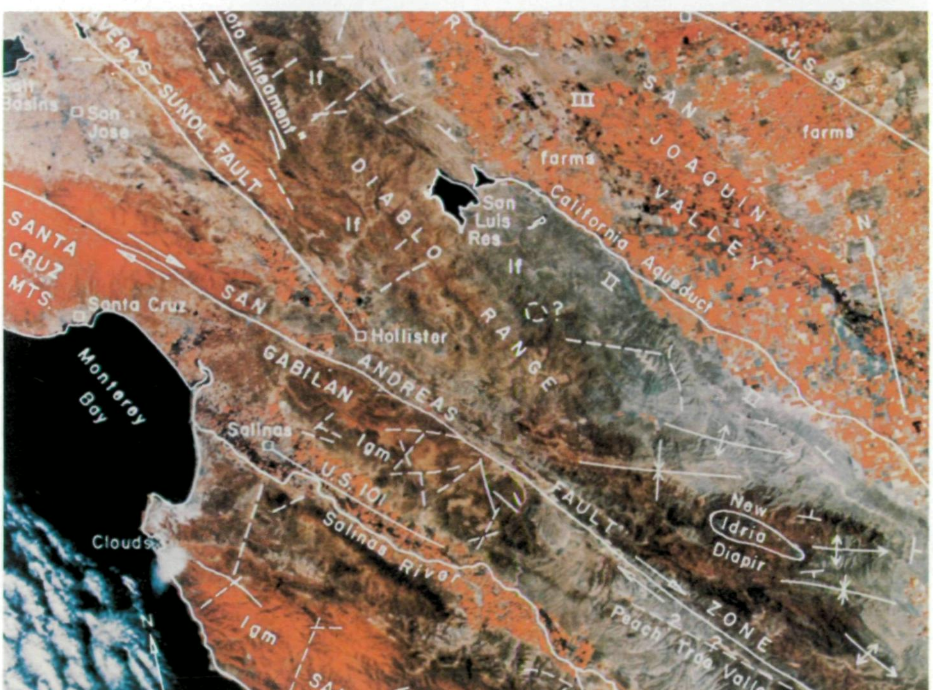
No satellite has stirred more excitement than a natural resources satellite called LANDSAT-1. Historians of the future may compare its development with that of the wheel or fire, so

From the Skylab space station in Earth orbit, Earth resources photo traces the flow of the Mobile River and its sediment-laden currents into Mobile Bay.



For the first time a giant photo map of the contiguous 48 states could be pieced together with 595 cloud-free black and white pictures taken by NASA's LANDSAT 1. The Department of Agriculture's Soil Conservation Service assembled the map on a scale of 1:1,000,000.





Geologists readily outlined the contours of the San Andreas Fault and other features in California on this LANDSAT 1 picture.

revolutionary and so basic may become its ultimate impact on human society. Launched nearly three years ago, LANDSAT-1 has opened whole new fields of Earth studies. Scanning the Earth every 18 days, its sensors record the unique signatures radiated by land, water, minerals, vegetation and man-made structures. Using these signatures, scientists have achieved some dramatic applications.

LANDSAT's imagery has provided the raw data to haul polluters of air and water into court. It has led geologists on oil and mineral hunts in Alaska, Oklahoma, the Rocky Mountains and the jungles of Brazil. Biologists have been able to predict potential fishing grounds. Changes in ecology brought on by forest fires, earthquakes and strip mining have been plotted. Municipalities guide urban development by determining in advance how projected growth patterns will affect transportation needs, public service facilities and the environment. LANDSAT alerted the hardpressed nations of Africa's drought-stricken Sahel region to the possibility of reclaiming desert areas for productive use through controlled grazing.

LANDSAT's potential for agriculture is staggering. Farmland of an entire region can be sorted crop-by-crop in a matter of hours in combination with high-speed computers. The end result is a computer-printed terrain map showing precise location and area of each crop type by symbol—C (corn), S (soybean), W (wheat), etc.

At the November 1974 World Food Conference in Rome, Secretary of State Henry A. Kissinger stressed

Healthy crops are bright red, suburban areas light pink, and barren land light gray in a composite photo of Cyprus from LANDSAT 1. NASA's Goddard Space Flight Center put it together with green, red, and infrared pictures made by the satellite from 568 miles above.

satellite surveillance techniques of the kind pioneered by LANDSAT-1 as an important tool for improving food distribution and the nutritional standards of the world's hungry millions.

The first step in this direction began in January 1975 with the launch of LANDSAT-2, which has been assigned a key role in America's ambitious Large Area Crop Inventory Experiment. The project combines LANDSAT imagery with meteorological data from weather satellites and ground stations to establish and refine procedures for predicting major crop yields. If successful, the project could evolve into follow-on programs of enormous benefit to producers and consumers alike. By pinpointing areas of food shortages and surpluses far enough ahead, inequities in supply and demand might be smoothed out, soaring food costs curtailed and hunger alleviated as a global problem.

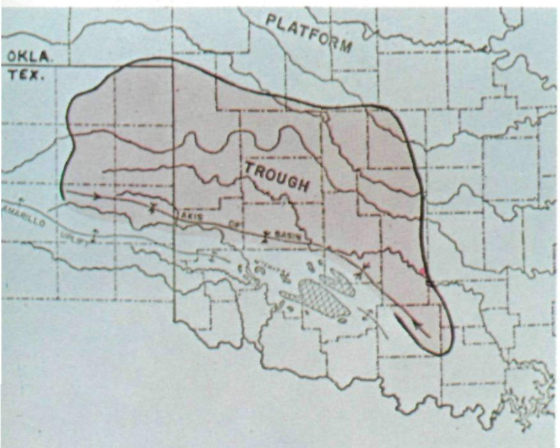
Communications

It's hard to remember a time before intercontinental television and the ubiquitous words "via satellite" commonly appeared on news programs. It was just 10 years ago.

The first one-hour television program linking Europe and America cost $22,350. The cost is now $5,120. The monthly charge for a telephone circuit between New York and Europe fell from $10,000 to $4,625 during the same span.

Satellites overcome the problems and limitations of submarine cables, land lines and ground radio stations. Unlike Earth-bound communications systems that operate between two

To check up on LANDSAT 1's ability to find oil, the satellite's cameras were aimed at the Anadarko Basin *(below)*, an area in Western Oklahoma throughly known to geologists. The LANDSAT task was to find hydrocarbons trapped 900 to 3,000 feet deep. Its picture *(bottom)* shows so-called "hazy" areas not recognizable in ordinary aerial photos. Of 35 such areas, some of which are outlined here, 33 corresponded to *producing oil fields* or *drilled structures.*



points only, satellites connect all stations in the area they cover. The largest oceanic cable, for instance, can carry a maximum of 1,840 conversations, and no television. Communications satellites, on the other hand, have a capacity of more than 3,000 simultaneous telephone circuits, and can carry color television as well.

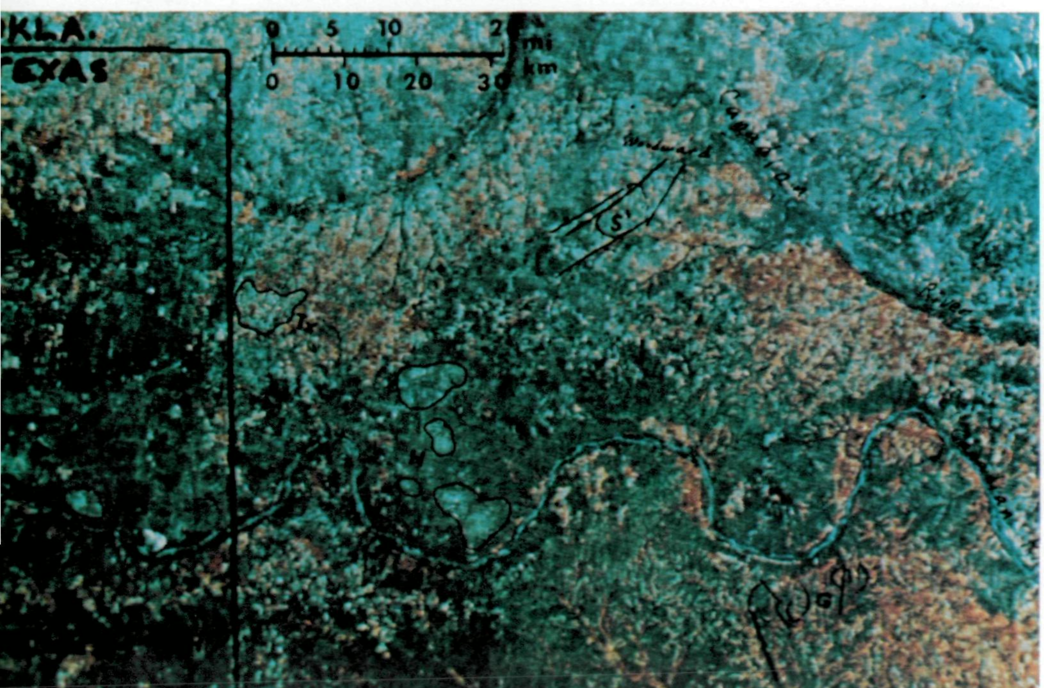
When placed in synchronous or stationary orbits above the Atlantic, Pacific and Indian Oceans, a set of three satellites can reach every point on the globe, making the dream of reliable worldwide communications a reality. A stationary orbit has the satellite, at 35,680 kilometers (22,300 miles) altitude, matching the Earth's rotation so that it hovers over one spot on the Equator.

Recent years have seen significant advances in satellite communications. The sixth in a series of eight planned INTELSAT IV global communications spacecraft was launched by NASA in 1974 on a cost-recoverable basis for the International Telecommunications Satellite Organization, which numbers about 90 member nations around the world.

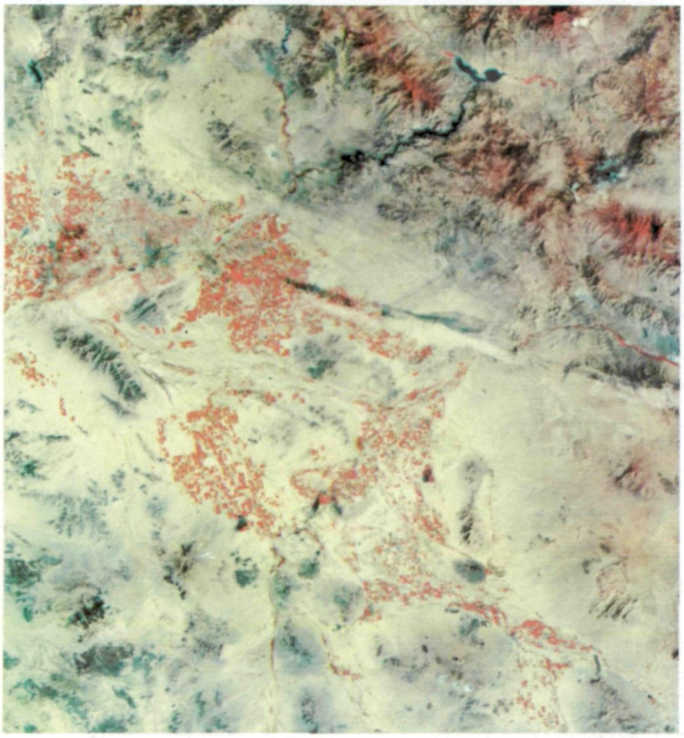
The INTELSAT spacecraft are the world's first and largest international communications carriers. Their cultural and economic impact on society is unquestionable. News and social events are carried to hundreds of millions of people around the world as they happen, pushing back the barriers of misunderstanding, distrust and ignorance. INTELSATs for example, brought the world the stirring moment when Neil Armstrong took man's first step on the Moon, and allowed the world to follow former President Nixon's momentous state visit to China. They also gave the world a ring-side seat at the 1972 Olympic Games, last year's World Cup Soccer matches and the Ali-Foreman heavyweight championship fight.

The world's first domestic commercial communications satellites—Westars 1 and 2—were launched by NASA for the Western Union Company. (The company reimbursed NASA for the cost of the launches.) Each Westar can provide thousands of commercial telephone and telegraph links as well as several color television links between New York, Chicago, Los Angeles, Dallas and Atlanta.

Since July 1974, NASA's Applications Technology Satellite-6, the most complex, versatile and powerful communications satellite ever developed, has brought education and



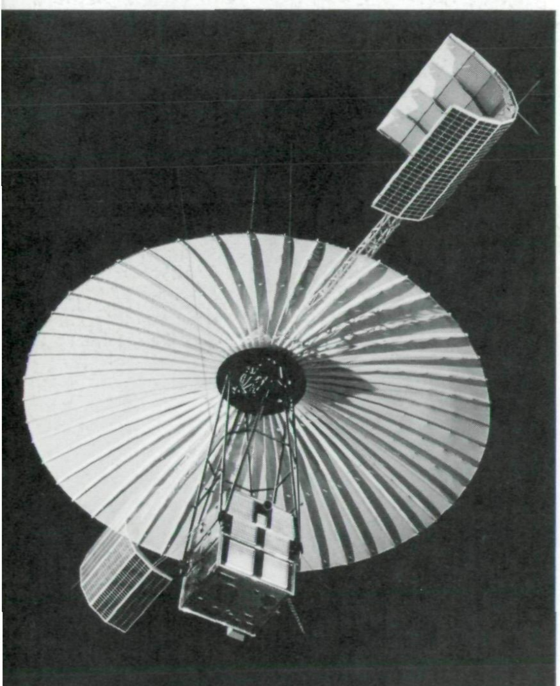
The ravages of strip mining can be monitored through the camera eyes of LANDSAT 1 almost as plainly as in the aerial photograph *(top right)* of a Kentucky region. The satellite pictures show strip mining sites in Ohio *(left)* and Arizona *(bottom right)*.



medical help to schools, hospitals and medical clinics in remote parts of the U. S. equipped with low-cost ground stations.

From its stationary orbit above the Equator, ATS has beamed special remedial reading courses to teachers in sparsely populated areas of Appalachia.

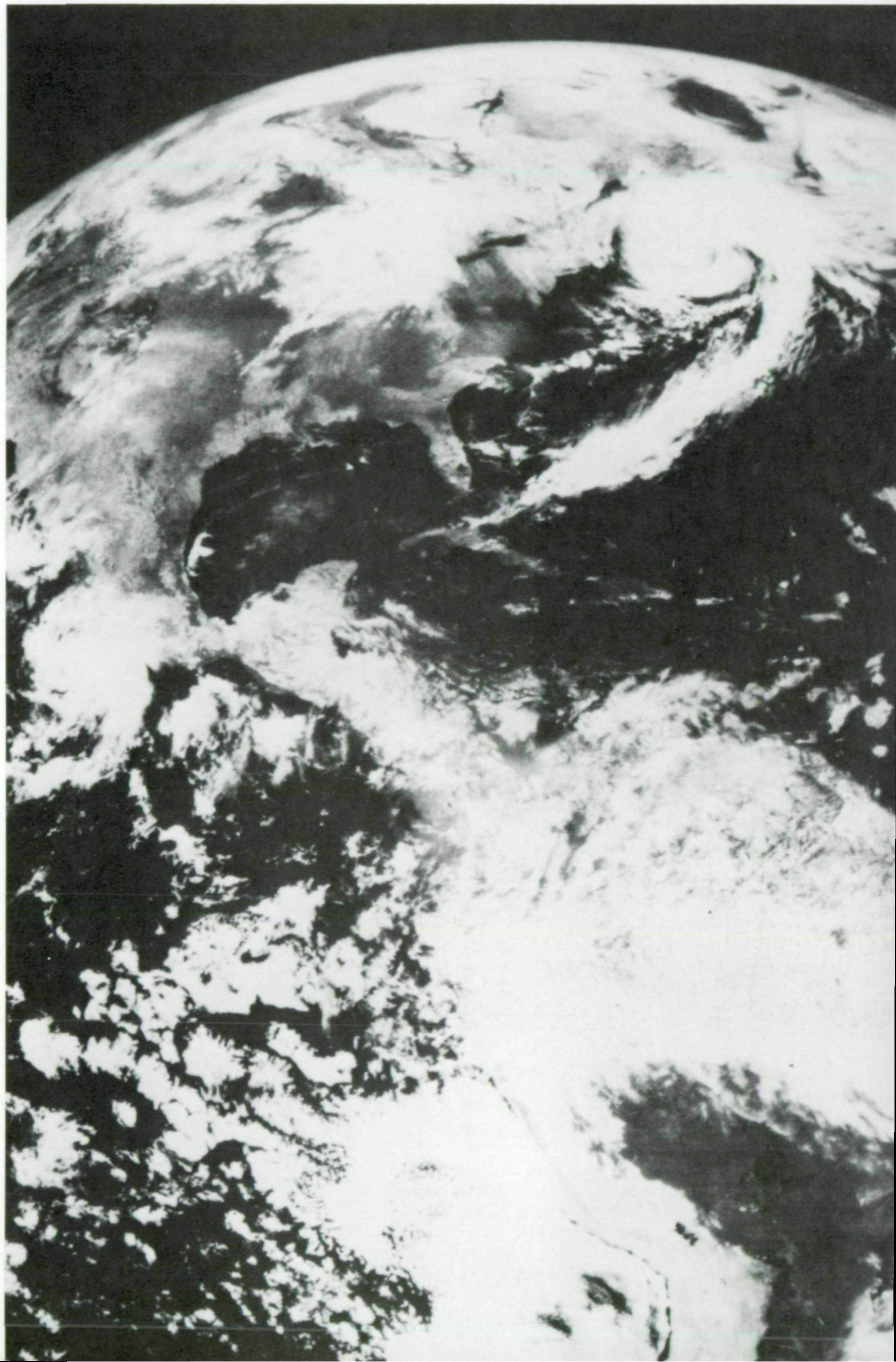
In the Rocky Mountain region, 56 rural schools in eight states received a variety of classroom programs and career guidance courses. Nearly 5,000 students and hundreds of teachers, administrators and counselors were involved. Half the receiving sites are equipped with low-cost,



Test model of Applications Technology Satellite.

Synchronous Meterological Satellite 1, shown here before launch on May 17, 1974, keeps station in orbit about 22,300 miles up and watches the weather throughout the Western Hemisphere. It delivers a picture of atmospheric conditions each half hour.

Photo from synchronous weather satellite shows most of continental U. S. and part of South America.



two-way communications facilities, making possible live participation in seminars from such out-of-the-way places as Cuba, N.M., Blanding, Utah, and Riverton, Wyo. Community education programs ranging from alcoholism to old age and health care are also offered.

In Alaska, 18 communities in remote areas with no previous TV reception of any kind took part in two-way classroom instruction sessions via Applications Technology Satellite 6. In addition, the system was used for telemedicine experiments. Doctors in remote outposts consulted directly with top specialists, transmitting patients' records and X-rays and actually examining the patients before television cameras in live, two-way voice and picture transmissions.

The satellite's capability was emphasized dramatically in January 1975 when a doctor in Seattle, Washington used two-way television contact via the satellite to instruct a nurse in Alaska's northern wilds as she performed surgery to save the life of a badly injured Eskimo.

Ten Veterans Administration hospitals in the continental states used Applications Technology Satellite-6 to provide live, interhospital exchanges of medical data, patient case studies and inservice training seminars for doctors and medical personnel.

With the repositioning of Applications Technology Satellite-6, in mid-1975, over Lake Victoria in East Africa it was available as a major communications link for the joint U.S.-U.S.S.R. manned space mission and for later use by the Government

of India in broadcasting subjects ranging from basic literacy to agriculture, family planning and hygiene.

The Atmosphere

No tool save the computer has advanced the science of weather forecasting as rapidly as the satellite. Two in particular, Nimbus and the Synchronous Meteorological Satellite, have added a new dimension to meteorology.

Nimbus, circling the Earth in polar orbit at an altitude of 1,120 kilometers (700 miles), records temperatures and maps weather formations over the entire globe twice a day. Its microwave sensors look right through any clouds to map and track ice flows and icebergs in the arctic and antarctic. The Navy has described the mapping of ice movements by Nimbus as an "indispensable service to the safe operation of world shipping lanes." Nimbus also maps both the Gulf Stream and Humboldt Currents daily to determine the dramatic weather effects they propagate hundreds of miles inland.

Nimbus also has the unique ability to monitor rainfall amounts, which is providing a new insight into global rainfall patterns that may eventually give scientists the means to predict droughts, floods and other weather phenomena that play havoc with world food supplies.

Synchronous Meteorological Satellites—there are two of them in stationary orbits, above Brazil and the eastern Pacific—monitor weather in the United States every 30 minutes, day or night. Infrared sensors, with the capability to "see" in darkness as well as daylight, tracked Hurricanes Carmen and Fifi continuously from birth to death in 1974, providing the first full-time surveillance of a monster tropical storm. As a result, lives and property were saved through adequate warnings. In addition scientists were able to learn more about the formation and erratic behavior of these tropical tempests which plague the North American continent.

Tornado development comes under the watch of satellites as well. Suspicious weather formations that might spawn destructive tornadoes can be scanned at five-minute intervals, allowing for earlier warnings of these killer winds. The satellites also perform as space data collection centers, relaying to ground centers information on tides, river currents, wind velocities and rainfall amounts collected automatically from hundreds of unmanned stations and ocean bouys on the surface below.

The ability to make direct and indirect observations of weather phenomena from the ground and from space has given meteorologists the capability to extend the accuracy and length of weather forecasting to a degree never before possible.

The Oceans

As the ocean lanes become more crowded and the vessels larger, the need for adequate communications and information on sea conditions become more acute. Here, too, applications satellites will have a key role, with NASA launching maritime commercial communications satellites called Marisats.

From vantage points over the Atlantic and Pacific Oceans, the Marisats will provide the first continuous, real-time communications network for ships at sea. The system, which carries voice, teletype, facsimile and high-speed data transmissions, will have a quality and reliability far exceeding current methods of ship-to-ship and ship-to-shore communications.

Later in the decade, a series of experimental oceanographic satellites known as Seasats will provide continuous monitoring of ocean conditions, keeping watch on storms, currents, ice fields and weather conditions. They also will accumulate information on the curvature of the oceans; ocean circulations; the transport of mass, heat and nutrients by surface currents; and interactions between air and water.

An operational network of Seasats could provide individual ships at sea with twice-daily maps of their specific routes, showing weather conditions and hazards. In time, Seasat data could influence ship design, port development and the selection of sites for such off-shore facilities as power plants.

Applications satellites give man the ability to observe and measure on a global basis the phenomena that affects his everyday life—rapidly, accurately and economically. They are perhaps the most important product of the space age, for they see no political divisions or geographic boundaries, and serve only to improve the quality and security of life for everyone.

Technology arrived at by exploring space is being applied in the factory, on the road, and in the hospitals. The young leukemia patient *(1)* is being bundled into a biological isolation garment derived from the astronaut's space suit to protect her while outside the sterile treatment room. Patients as old as Mrs. Helen Chambers, 76 *(2)*, and as young as Jeni Guarascio, 3, who appeared with NASA executives before the House Committee on Science and Astronautics *(3)*, benefit from the rechargeable heart pacemaker *(4)*. At the Jet Propulsion Laboratory *(5)* engineers Harry Cotrill *(left)* and Jack Rupe test a new anti-pollution fuel of gasoline, hydrogen, and air in an auto engine. Out of NASA's study of propellants under zero gravity came the prototype of a ferrofluid machine *(6)*, which can separate nonferrous metals, such as zinc, copper, and aluminum, from automobile scrap.

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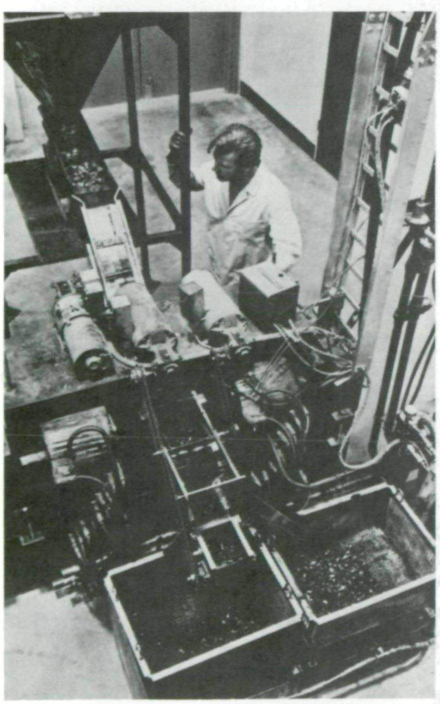

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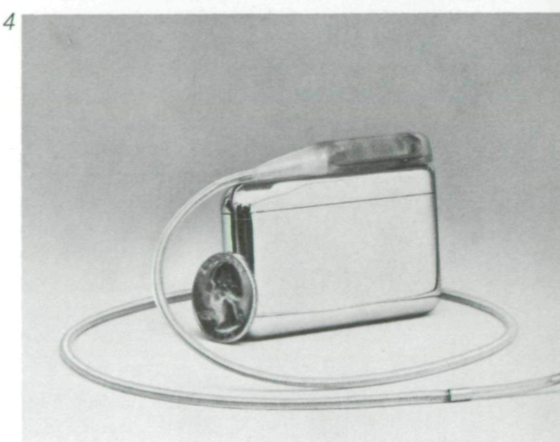


The Planets

We study the planets to learn more about the origin and evolution of the solar system of which Earth is a part. Since the planets are in various stages of evolution, they function as galactic "time machines", allowing us to see where we have been and where we are going.

We study the planets to answer man's oldest and most intriguing question: Are we alone in the universe? The discovery of life of any kind elsewhere in the solar system would presume the existence of intelligent civilizations in other parts of the Galaxy.

We study the planets because we cannot ignore the possibility that time and the ravages of man may require new abodes in the heavens for the preservation of the human race.

Finally, we study the planets to unlock the secrets of the dynamic processes at work in the solar system and to learn more about the formation and development of phenomena that bear directly on Earth's environment and the needs and security of all humanity.

While the benefits derived from exploration of the planets must be measured in decades and cannot be evaluated in terms of specific costs, potential returns directly applicable to man's interests on Earth are already beginning to materialize.

A decade ago, for example, the unmanned Mariner 4 spacecraft made the surprising finding that radiation played an important part in dictating the weather on Mars. In Earth weather models, radiation had always been omitted as being a negligible factor. Following the Mars' results, radiation effects were added to analytical weather models and substantially improved the accuracy of weather predictions on Earth. This application of comparative planetology has been well documented by the National Academy of Sciences.

It has long been established that a sustained drop in the average temperature of the Earth's atmosphere of only about 4 degrees C (7 degrees F) could trigger another disastrous ice age. This has raised the question of whether smoke, dust and other pollutants being pumped into the Earth's atmosphere could cause a rise or fall in global temperatures by blocking heat from the Sun or by preventing radiated heat from escaping back out into space. NASA's Mariner 9 spacecraft, which orbited Mars for nearly a year back in 1971-72 and returned detailed information about the planet, provided a direct answer. By a stroke of fate, Mariner 9 reached Mars during the height of a monstrous dust storm that had raged for months and had completely surrounded the planet. The spacecraft continually recorded temperature profiles of the planet as the thin Martian atmosphere went from a dust-filled condition to a clear state. The result? The heavy and prolonged concentration of dust particles in the Martian atmosphere caused a drop in surface temperature of over 20 degrees C (36 degrees F), a strong indication that a comparable degree and duration of pollutants in the Earth's atmosphere could indeed set off another ice age.

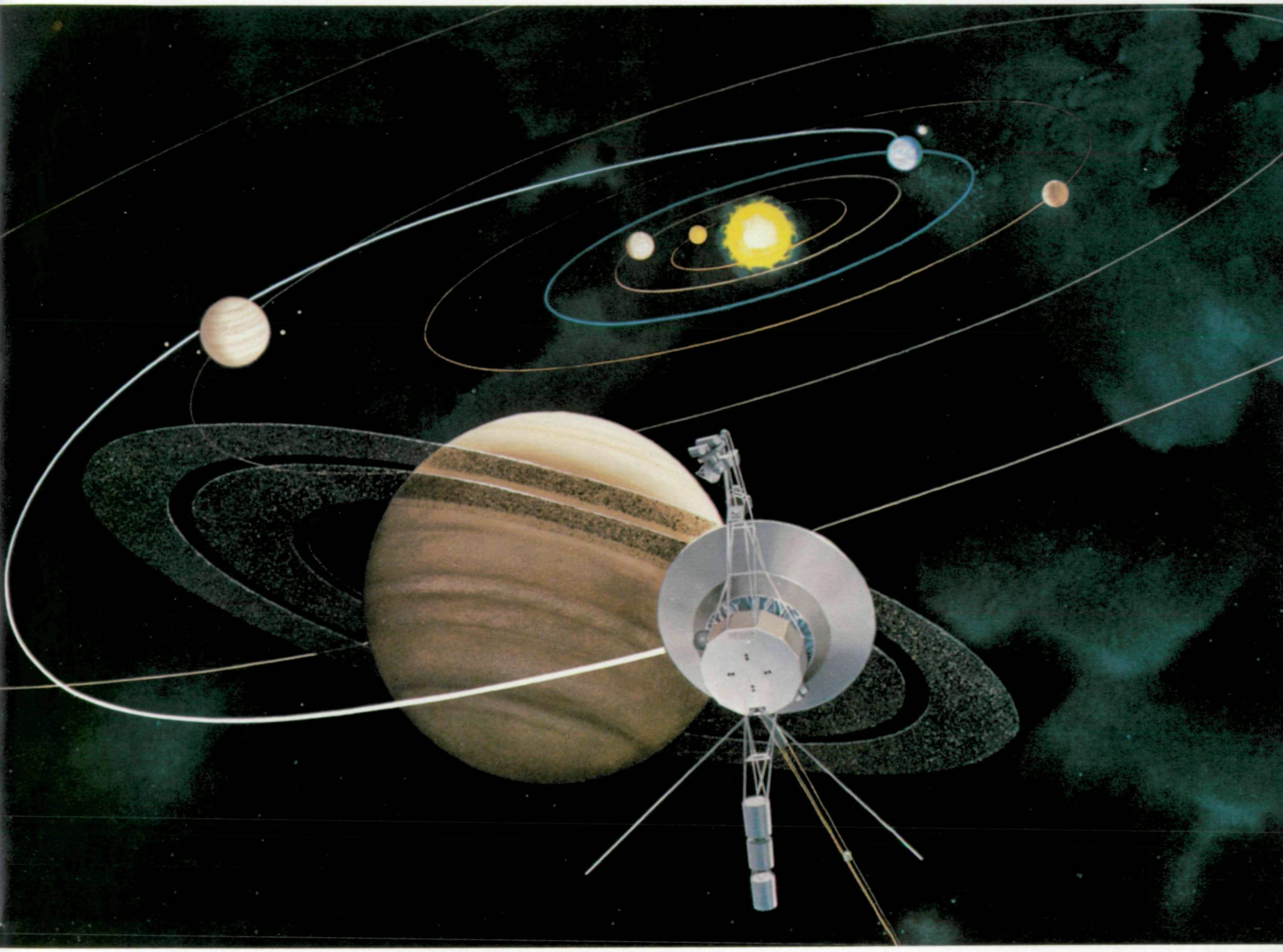
Mariner 9 also provided data directly related to another atmospheric concern on Earth, the long-term effects of certain pollutants on the Earth's vital, high-altitude ozone layer. Ozone depletion could have serious consequences for all life on our planet since the layer absorbs most of the Sun's dangerous ultraviolet radiation. A decrease in total ozone protection over an extended period could increase the incidence of skin cancers in fair-complexioned persons.

The environmental impact of ozone depletion has been highlighted in recent years by studies of high-altitude aircraft operations where jet engines exhaust oxides of nitrogen and water vapor, both of which were previously thought to be involved in ozone destruction mechanisms.

Noting the correlation between the disappearance of ozone in the Martian atmosphere and the release of water vapor from the planet's polar caps in the summer season, Mariner 9 confirmed the high reaction rate of water on ozone. However, Mariner 9 also detected ozone replenishment mechanisms in the Martian atmosphere that removed water vapor as a serious villain. It is now known that nitrogen oxides pose the real danger to Earth's environment. The solution to the nitrogen-oxide problem, however, is within reach of advanced technology.

Mariner 10's flyby of the planet Venus in 1974 also shed new light on the Earth's weather mechanisms. Back in the 1700's a British astronomer named Hadley wrote a classic paper stating that a solar-driven circulation of air from the equator toward the poles is a driving force behind weather on Earth. Meteorolo-

Sometime in 1979, an unmanned Mariner is to fly by the ringed-planet Saturn.



gists have widely believed in that principle, but have never been able to confirm it. Even with excellent satellite pictures, the cloud patterns in Earth's atmosphere are so confused by various storms and cyclonic patterns that this overall Hadley-cell circulation concept is completely obscured.

Then came Mariner 10's first pictures of the Venus cloud belts. It is impossible to overexaggerate the excitement of leading meteorologists when the pictures revealed the Hadley-cell circulation pattern exactly as drawn in Hadley's classic paper two centuries ago. Meteorologists "knew" this was a main driving force behind Earth's weather. Now they could finally show the phenomenon. It has been predicted that the Mariner 10 photographs will stand beside Dr. Hadley's drawings in every meteorology textbook published for the next 100 years.

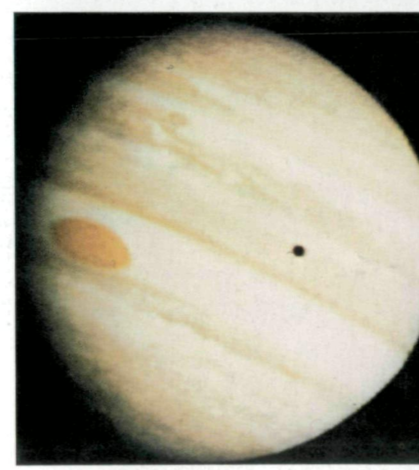
The planet Mercury came under man's close scrutiny for the first time in history during Mariner 10's journey through the inner solar system. Using Venus' gravity as an assist, it entered a solar orbit that brought it close to Mercury on three separate occasions. It was the first time that a spacecraft from Earth had used one planet's gravity to steer it toward another.

The first telecast from Mariner 10 showed surface details that were as small as 300 feet wide and led onlookers at first to think that Mercury, with its highlands and plains, also resembled the Moon and Mars. The features even suggested a lightweight crust of silicate composition similar to the Moon's. But Mercury also has a region of hills and furrows, covering hundreds of square miles, that is unlike anything on Mars or the Moon. Mariner 10 also startled scientists by discovering that Mercury has an atmosphere. Not much of an atmosphere, to be sure; it amounts to less than a trillionth of that which cloaks the Earth and is composed chiefly of helium.

The three flybys of Mercury by Mariner 10 put into question a commonly-held theory about the magnetic fields of planets. It has long been believed that the magnetic fields are generated by a dynamo-like action involving liquid interior material, such as a molten, iron-rich core, and fairly fast rotation rates of the planets. However, Mariner 10 detected a significant, intrinsic magnetic field on Mercury and that planet rotates very slowly. Perhaps the magnetism is a remnant, left over from an earlier epoch when Mercury spun fast enough to generate such a field. The Mercury data should encourage new and better theories on the generating mechanism behind planetary magnetism, which may, in turn, yield new insight into the forces behind earthquakes.

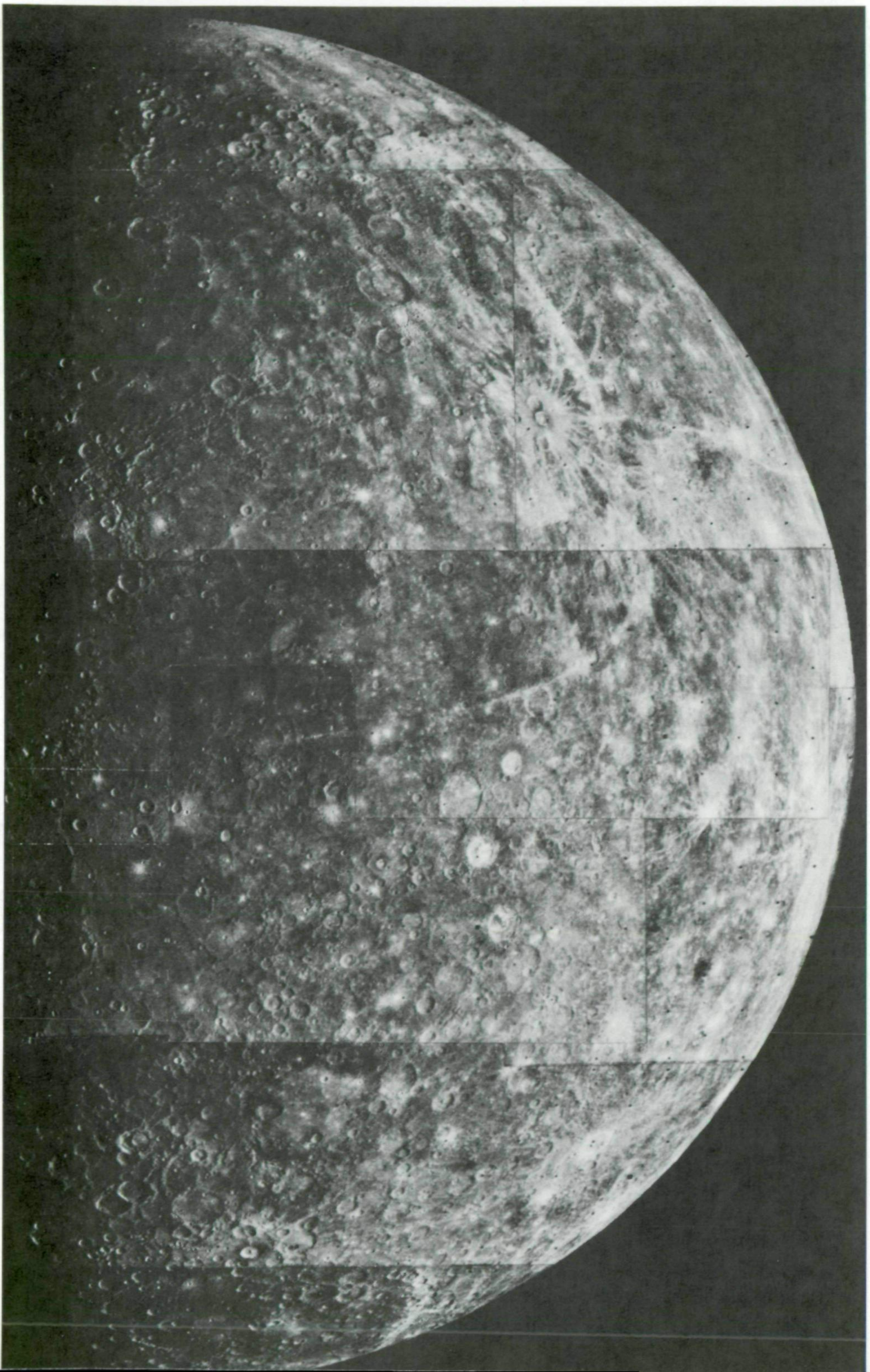
Of all planetary voyages, few have stirred the imagination like those of Pioneers 10 and 11. These unmanned robots completed 22-month, 640-million-mile journeys into the outer solar system to whip past the giant planet Jupiter at altitudes of 81,000 miles and 29,000 miles.

Pioneer 10, passed Jupiter on Dec. 3, 1973, and rode the planet's gravity into a new trajectory that will take it out of the solar system into the great



Mariner 10 took three close looks at heavily-cratered Mercury (below) and one at cloud-cloaked Venus (top, opposite page), discovering, among other things, that the Venusian cloud patterns may provide important clues to understanding weather on Earth.

Pioneers 10 and 11 found the giant planet Jupiter (bottom, opposite page) had a hotter core than expected.



galactic veil beyond, the first object of man on a course to the stars. Pioneer 11 glided past Jupiter on Dec. 2, 1974 and, using the pull of Jovian gravity, curved back across the solar system for a 1979 rendezvous with the ringed wonder of our planetary system, Saturn.

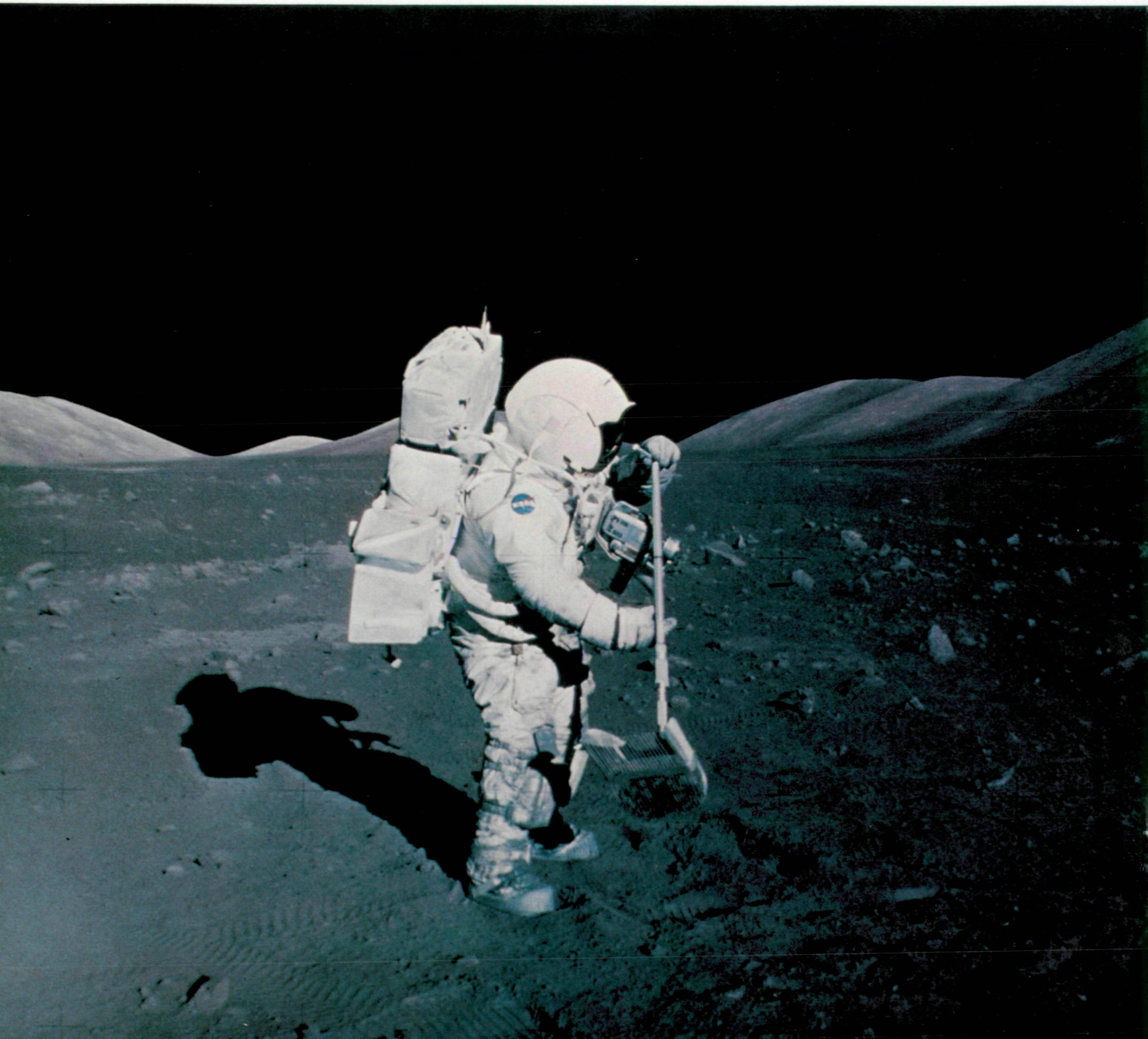
What the Pioneers found out about Jupiter bolstered the theory that it is a huge spinning ball of what is almost entirely liquid hydrogen. Its Great Red Spot may be the vortex of a storm, not unlike a hurricane, which rages over 20,000 miles and towers like an Earthly thunderhead some 5 miles above the surrounding clouds. The storm apparently has been in progress for hundreds of years.

Jupiter turned out to be even hotter than many had expected, perhaps as much as 30,000 degrees C (54,000 degrees F) at its core. This is nearly six times as hot as the surface of the Sun. The temperatures abate from the center outward, falling to about −12 degrees C (10 degrees F) just below the cloud tops.

Could life exist under such conditions?

The answer is a qualified yes. Presumably in a region somewhere between the holocaust at the Jovian core and the chill among the clouds, there are temperatures as moderate as Earth dwellers like in their homes. In such a region, from the methane, ammonia, and water known to be in Jupiter's atmosphere and the activity seen to be seething there, life could burgeon. But Jupiter's high winds and violent updrafts and downdrafts could be killing off any organisms as fast as they form.

Scientist-astronaut rakes up rocks and rock-chip samples in the Taurus-Littrow region of the Moon.



Weather on Jupiter differs greatly from that on Earth. High and low pressure systems, which tend to be circular on Earth, girdle Jupiter in colorful ribbons of cloud, the brighter bands representing rising columns of air, the dark ones descending columns. The unvarying heat from Jupiter's fiery core tends to continuously generate the bands.

The Pioneers also had a look at Jupiter's big inner moons—Io, Ganymede, Europa, and Callisto—and found that at least one of them, Io, has an atmosphere. Pictures disclosed that Callisto has a small ice cap at its South Pole and revealed light and dark areas on Ganymede that resemble features of the Moon and Mars.

Planetary data may soon contribute substantially to a better understanding of the actions of plasmas, electrically conductive gases. Lack of knowledge about plasma dynamics is preventing the achievement of controlled thermonuclear fusion, which would solve Earth's energy problems for centuries to come. Unfortunately, plasmas are extremely difficult to study and understand on a small scale that can be tested in a laboratory. Much of our understanding is coming from space where great plasma fields exist naturally.

Pioneer 10 and Mariner 10 studies of the Jupiter and Mercury magnetospheres have shown thermoplasma effects that were totally unexpected. Plasma physicists now have new data of an entirely different nature to improve their basic understanding of the dynamics of plasmas.

One may confidently predict that planetary exploration and its offshoots will continue to advance in importance. Meteorologists trying to better understand Earth's weather, atmospheric pollution, and climate effects have been among the strongest advocates of the Pioneer Venus missions which will study Venus in 1978.

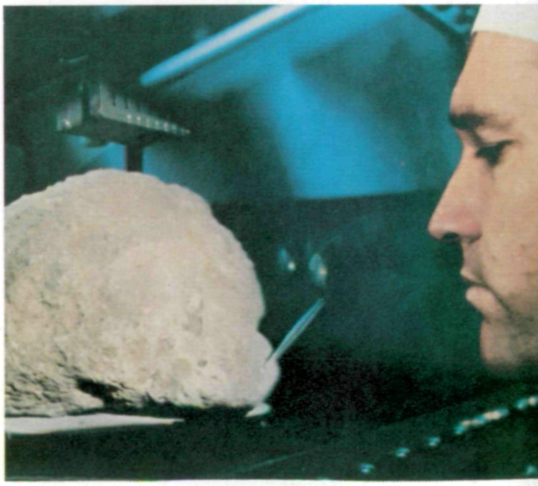
Similarly, the strongest supporters of the Viking missions that will soft-land payloads on the Martian surface have been biologists struggling to better understand life processes on Earth. They believe that any evidence which Viking will return on the processes which lead to the evolution of life will make a major contribution to the science of biology.

Steady progress is being made toward improving the picture of how the Earth and all the other planets formed and evolved in the solar system. One picture gaining credence is that the planets evolved from a similar origin into different states dictated by their proximity to the Sun and their relative sizes. Venus, being closer to the Sun than Earth, has advanced to the state where water has been driven off and carbonates broken down in the crust to create a thick atmosphere of carbon dioxide, making the planet totally uninhabitable. Many scientists believe that Earth is heading in this direction and that the evolutionary process which would normally take several billion years could be drastically accelerated by the polluting effects of man and his machines.

Mars appears to be trailing in evolution and is still in the process of forming its atmosphere and reaching a state of persisting liquid water on the surface. At least one leading scientist predicts that Mars will reach a habitable state at just about the time that Earth is becoming uninhabitable, and that human civilization will then migrate to colonize Mars. Whether this is true or not, it is safe to predict that a further study and comparison of the planets will give us the knowledge to better control spacecraft Earth, and prevent, or at least slow down, the process of getting into a runaway, uninhabitable state like Venus.

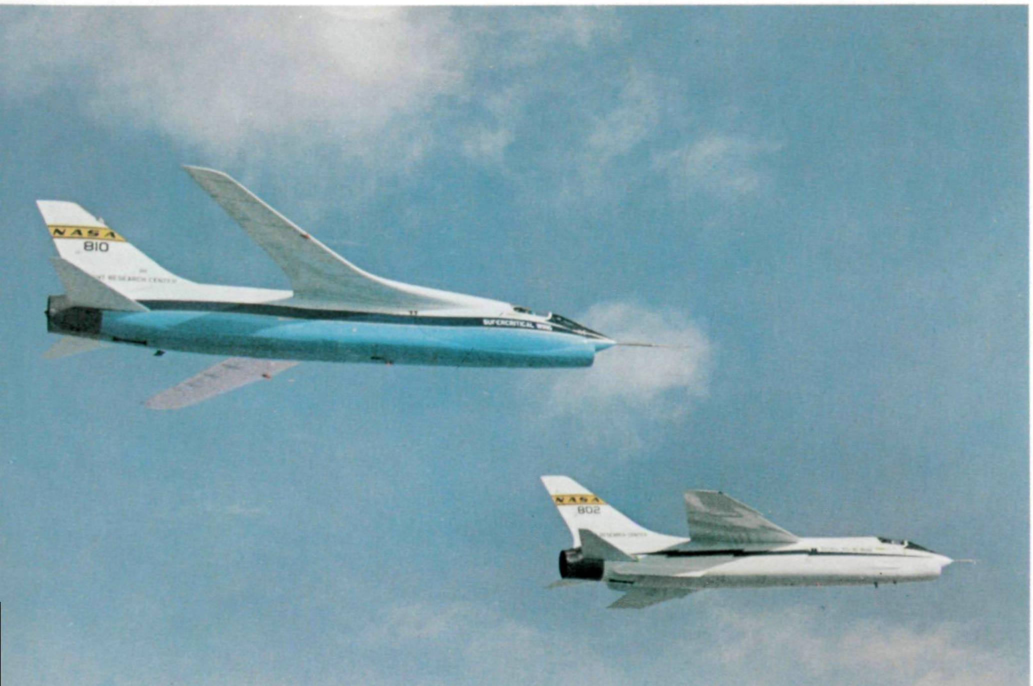
Investigations of the Moon are continuing as well from material brought back by Apollo expeditions and data still being sent back by the Apollo Lunar Surface Experiment Packages which the astronauts left behind. As a result, knowledge and theories of the Earth's earliest years have advanced. Study of large lunar boulders picked up on Apollo 17 established that one of them was 4.7 billion years old.

Less than two decades after the birth of the Space Age, we have written the preliminary chapters to the first phase of exploration of the solar system.



Technician examines one of largest rock samples returned from the Moon, a coarse-grained breccia and clastic rock weighing 8.98 kilograms (19.8 pounds).

Aeronautics



Modified Navy F-8's become NASA experimental aircraft for flight research and test of advanced concepts.

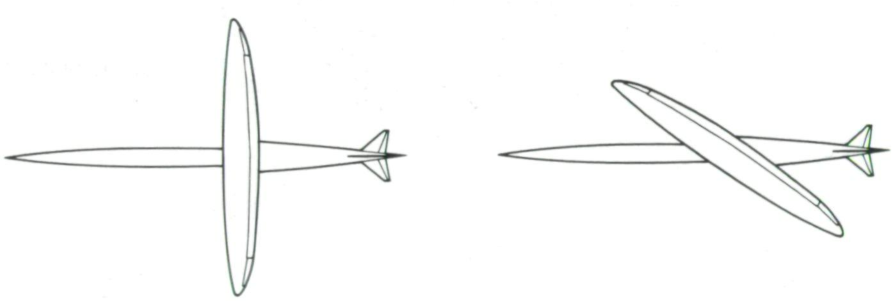
In 1974, fuel conservation became a household fact of life. In aeronautics, increased fuel costs and the possibility of reduced supplies raise the spectre of curtailed air transportation in the future that could have serious economic and social consequences.

As a result, NASA is sharply focusing attention on identifying and developing new technologies to achieve higher operating efficiences with existing aircraft and to produce large fuel savings in the next generation of air transports.

NASA has identified technologies, both near-term and those that can be ready in 10 years, with the potential of reducing fuel requirements of commercial jet aircraft by as much as 50 percent. If these advances were incorporated into the number of commercial aircraft flying in the U. S. today—approximately 2,100—it would save nearly 350,000 barrels of oil per day. When based on estimates of fleet size in the 1985-90 time period, savings could reach as high as 45.6 billion liters (12 billion gallons) of jet fuel annually, or nearly 1 million barrels of oil every day. This translates into a hefty $3 billion each year.

These savings will be achieved through reduced air resistance (drag), reduced weight, more efficient engines and control systems, new design concepts and better operating procedures in the air and on the ground.

Studies show that a supercritical wing developed by NASA can effectively reduce both drag and weight. A jet aircraft using the wing has been flown successfully, and virtually all aircraft companies are planning to



Oblique-wing concept of an air transport (viewed from above) has wing at right angles for takeoff and landing, left, and in canted position, right, for high-speed cruise.

Illustrations depect promising applications of advanced technologies to a fuel-thrifty commercial aircraft concept (bottom) and, to light aircraft (top). GAW-1 is a version of the NASA-developed supercritical wing.

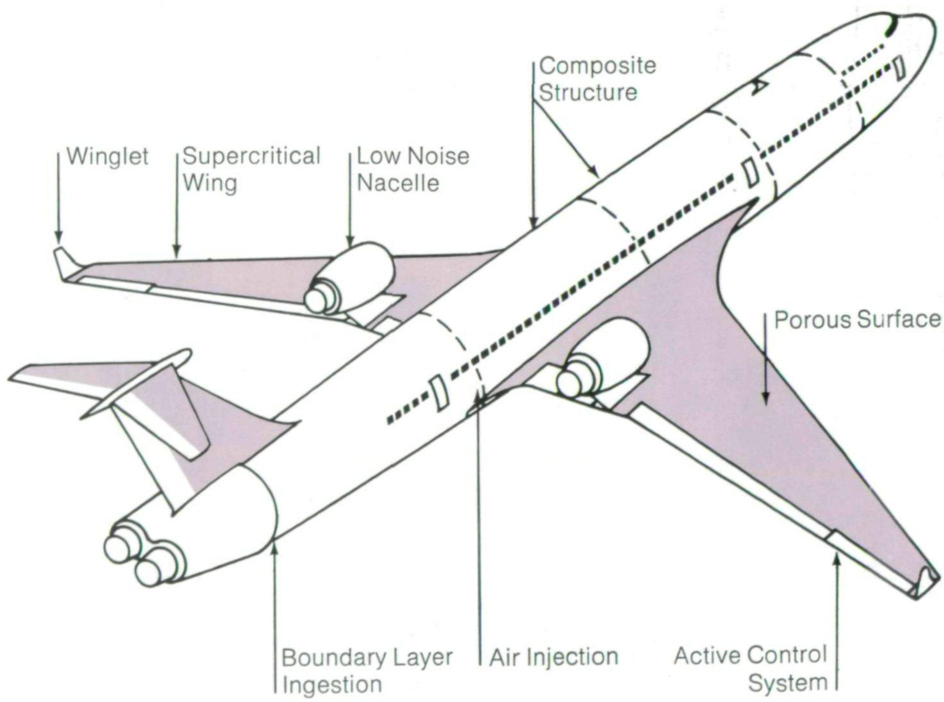
use some version of it. Supercritical wings can increase aircraft fuel efficiency by about 15 percent.

Another NASA design innovation, the oblique wing, potentially can enable high-speed aircraft to use less fuel than current swept-winged jets during takeoff and landing and while cruising at high altitudes. The wing crosses the airplane's fuselage at right angles for takeoff and landing and pivots to cross diagonally for high-speed flight.

Other design features to reduce air friction and drag include small winglets mounted on the wingtips to break up spiraling wind patterns and porous or slotted skins for wing, tail and fuselage surfaces.

An advanced flight control system, called digital fly-by-wire, which is fast acting and computer coordinated has been tested by NASA. Equipping aircraft with this system not only will improve handling qualities and enhance flight safety, but can be used indirectly to reduce aerodynamic loads and structural weight. Lightweight wires replace the heavy system of metal rods, hinges and hydraulic lines that previously translated the pilot's signal from the cockpit to the aircraft's control surfaces. The total weight reduction can significantly increase passenger and cargo capacity per gallon of fuel. It is estimated that aircraft modified with fly-by-wire systems could fly about 15 percent farther on the same amount of fuel. Airplanes built with the system from the outset would do even better.

Composite materials—strong, lightweight combinations of metals



and plastics such as boron or graphite epoxy—that can reduce aircraft weights by more than 30 percent compared to aluminum structures are being developed and tested by NASA in collaboration with manufacturers and airlines. Composite materials used for aircraft construction could realize fuel savings of 10 to 15 percent.

Today's fan-jet engines are marvels of efficiency compared to the first jet engines that entered commercial service in 1958, delivering about three times the passenger miles per gallon. Fuel-conservative engines that are lighter, cleaner burning and 20 percent more efficient are being studied by NASA. In addition, research is underway on advanced engine designs involving completely new concepts. For example, a new engine cycle that reuses engine exhaust heat is expected to consume 30 percent less fuel than today's most efficient aircraft powerplants.

A variable-cycle engine which is somewhat analogous to the variable sweep wing used on advanced military aircraft like the F-111 is also under study. Here, the internal engine geometry rather than the wing geometry is altered in flight. Operating in a sense as a gear shift, it permits the engine airflow and direction of thrust to be adjusted for effective low-noise operation during takeoff and landing while maintaining high efficiency for supersonic cruise. Significant fuel savings are predicted for the new engine.

Dependence on petroleum and other fossil fuel sources may be reduced considerably through use of synthetic hydrocarbon fuels (derived from coal and oil) under investigation by NASA and the military services. Liquid hydrogen is also of interest because of its high energy to weight ratio. The most formidable problems associated with synthetic fuels lie in the system support areas of economical production, liquefaction, distribution, storage and handling.

Perhaps the greatest potential for air transport growth in the future is in the air freight field. Projected demand suggests the eventual development of very large air vehicles that will dwarf the largest wide-body transports flying today. NASA studies include consideration of lighter-than-air and semi-buoyant vehicles as well as conventional aircraft.

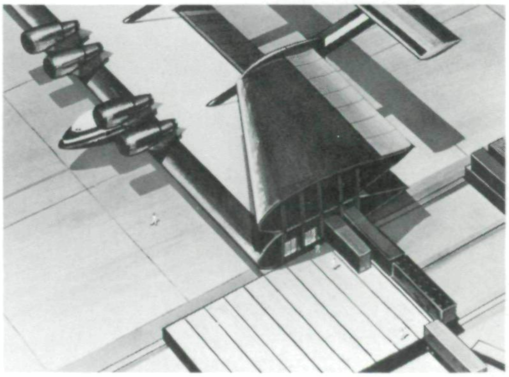
Large dirigibles using engines and wind for movement could carry enormous cargoes. The advantages in fuel consumption, noise and pollution are obvious.

Large, conventional cargo aircraft might carry their freight loads in the wings rather than the body. This would permit savings in structural weight since the distributed load balances the aerodynamic lift forces on the wing. The result is a potential payload increase on the order of 50 percent, with a corresponding decrease in operating cost and fuel per ton-mile.

Other advanced concepts being studied by NASA include: coupled aircraft in which the efficiency of wing-loading is augmented by individual smaller aircraft that can be hooked together to form larger flight units; tandem aircraft in which the large loads are carried in the body but supported by two wings; and large, conventional, low-speed airplanes in which advanced technology is deliberately avoided in favor of design simplicity and production costs.

As every businessman knows, time and money are directly proportional. In aeronautics, time spent in the air and on landing is directly related to fuel consumption, as well as traffic congestion and safety.

Recent studies by NASA include drag brakes for steeper approaches, more efficient air and runway traffic control and high-capacity landing gears for quick runway turnoffs. Sophisticated cockpit displays and automatic landing systems are being developed to reduce the pilot's workload and to permit routine maneuvers beyond the capability of an unaided pilot. The control and dissipation of trailing vortices (miniature tornadoes generated by the wings of large aircraft) will permit reduced aircraft landing separations, from the present



Cargo containers enter wing of futuristic air transport.

Aeronautics research in NASA extends from the high-performance YF-12 *(below)* right down to the noise on the ground around airports. The YF-12 is one of two at the Flight Research Center which provide information for the design of future aircraft. The Boeing 727 *(bottom)* has smoke pots near its wingtips to show the spiraling vortices which require smaller planes to keep 8 kilometers (5 miles) back, thus aggravating delays around airports.

three to five miles to about one or two miles, thereby decreasing congestion and stacking over and around terminals.

NASA technology also is being applied to noise reduction and aircraft design innovations for utility of service at air terminals.

In aircraft noise reduction, NASA can report good results from steeper approaches to airports, which keeps planes higher over much of the surrounding community and curtails the noise heard on the ground. In cooperation with the Federal Aviation Administration, the procedure was tested in regular airline passenger service. A United Air Lines DC-8 equipped with a sophisticated navigation system modified to suit such landing approaches succeeded in trimming the area of objectionable noise under the approach path by about 53 percent.

NASA has ground-tested and flight tested a modified JT8D jet engine that could reduce by at least 75 percent the total ground area affected by objectionable noise during approach and take-off. The JT8D engine is used in airliners that comprise over 60 percent of commercial aircraft used in the United States.

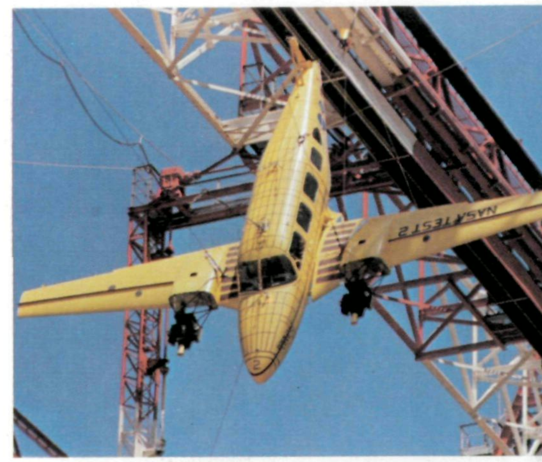
For the future, there is a promise of noise reduction in the redesign of engines and engine nacelles (housings). NASA also is working on short-haul experimental engines which would enable airplanes to use small airports close to terminal cities, not only reducing engine noise and exhaust, but also the need for new or expanded jetports. About 80 percent of air travel involves short-haul operations: intercity flights of under 500 miles.

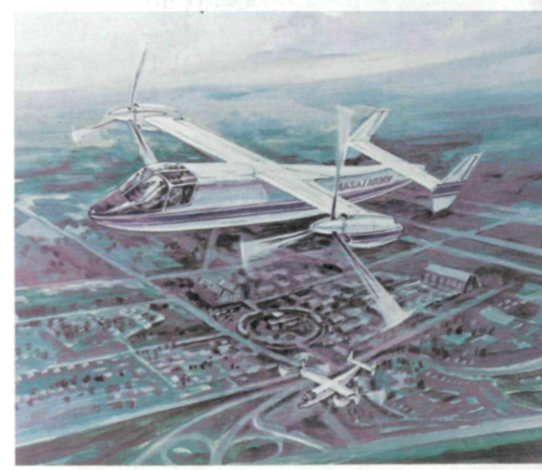
A tilt-rotor aircraft is under study for similar short-hop service. It has large rotors on its wingtips for vertical takeoff and landing, but when airborne, the rotors tilt forward for cruise like a conventional turboprop airplane. Under a NASA-U. S. Army program, two tilt-rotor research aircraft were scheduled for delivery in 1975.

Other research projects underway by NASA include the Remotely Piloted Research Vehicle program where the test pilot flies the aircraft from a cockpit on the ground. The advantage of this NASA-developed technique is that advanced technology can be investigated and high risk maneuvers can be performed very early in the flight test program without danger to the pilot. Additionally, scale models of aircraft are used that do not have to be man-rated. Consequently, a remotely-piloted flight test program may cost less than half that of a full-scale manned program. It is possible that remotely-piloted vehicles will in the future be found useful for specialized civil applications such as monitoring of severe storms, forest fire detection, fire fighting, disaster assistance, and deliveries to isolated locations.

Trends in aviation over the next two decades will be influenced by research and technology programs being conducted by NASA in cooperation with other federal agencies and the private sector. Aircraft noise impact on communities will be reduced drastically, and, above all, they will be fuel conservative to meet the realities of the energy shortage.

In an effort to improve light aircraft structures, available airframes are suspended and swung into the ground to simulate actual crash conditions and evaluate safety concepts.

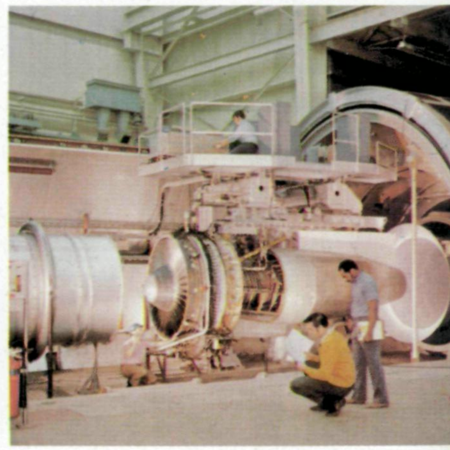




Two tilt-rotor aircraft similar to the one above will be tested for short-hop service under a NASA-U. S. Army contract.

Aircraft in Langley wind tunnel was modified to obtain greater aerodynamic lift while using the wing to shield some engine noise from persons below.

Hush-hush work that many will want to hear about continues at the Lewis Research Center on the world's quietest jet engine. Its performance with an acoustically-treated, sound-dampening intake is being measured.



Shuttle

Economical, routine and simplified access to Earth orbit.

That's the promise of the reusable Space Shuttle for all users—civil or defense, foreign or domestic, environmentalist or energy seeker—beginning in 1980, about a year after the new space transportation system makes its first manned orbital flight.

That's the time when space activities will experience a dramatic savings in terms of launching costs and expenditures for spacecraft and spacecraft components—welcome news for both commercial and nonprofit user organizations.

The Shuttle system is being developed by the United States to make space operations less complex and less costly as we continue to place such useful items as weather and communications satellites in orbit; to encourage mutually-beneficial international cooperation in space enterprises; and to extend human mobility (manned operations) in the space environment.

There are four major elements in the Shuttle system—the Orbiter, the Orbiter's main engines (that use liquid propellants), the external tank (for the liquid propellants), and the solid propellant boosters. The external tank is the only element that is expendable.

The Orbiter will be mated at launch to the large external tank and two solid-fuel rockets. Both solid rockets and the Orbiter's liquid-fueled engines will ignite at launch.

When the Shuttle reaches an altitude of about 40 kilometers (25 miles), the spent solid rockets will detach and parachute into the ocean to be recovered. The spacecraft will proceed toward Earth orbit. When the big propellant tank is no longer needed, that too will be jettisoned.

The Shuttle can function as an Earth-orbiting space station for as long as 30 days when it carries Spacelab in its payload bay. (See page 33). It can launch, retrieve, and repair orbiting satellites. At the end of the mission the piloted Orbiter will return to Earth and land like an airplane. It will then be refurbished for its next mission.

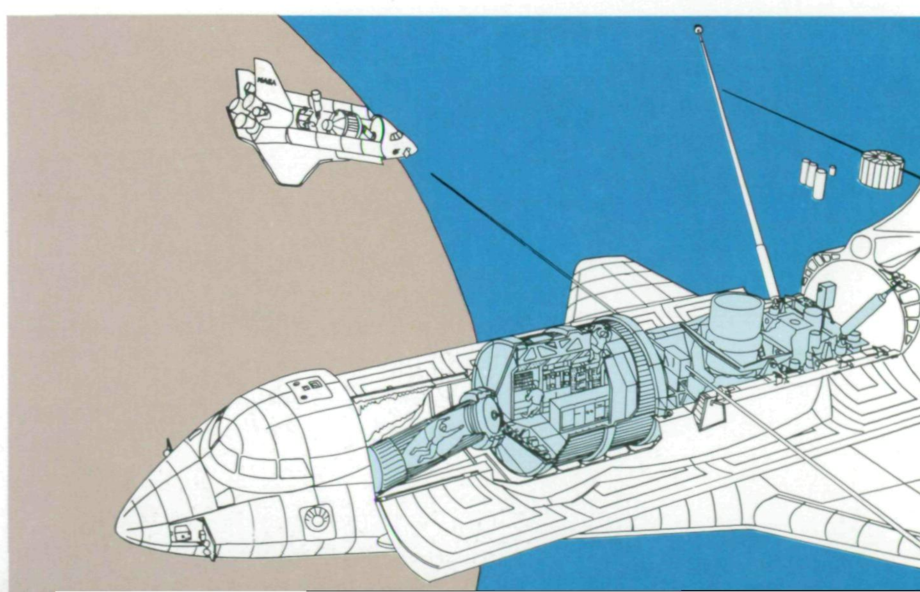
The Orbiter element, about the size of a DC-9 air transport, may be flown at least 100 times and perhaps as many as 500 times. The solid rockets can be reused 20 times.

The capability to repair and retrieve orbiting satellites means the satellites themselves can be made less expensively. Reliability requirements can be relaxed. For example, costly standby electronics systems and subsystems can be eliminated.

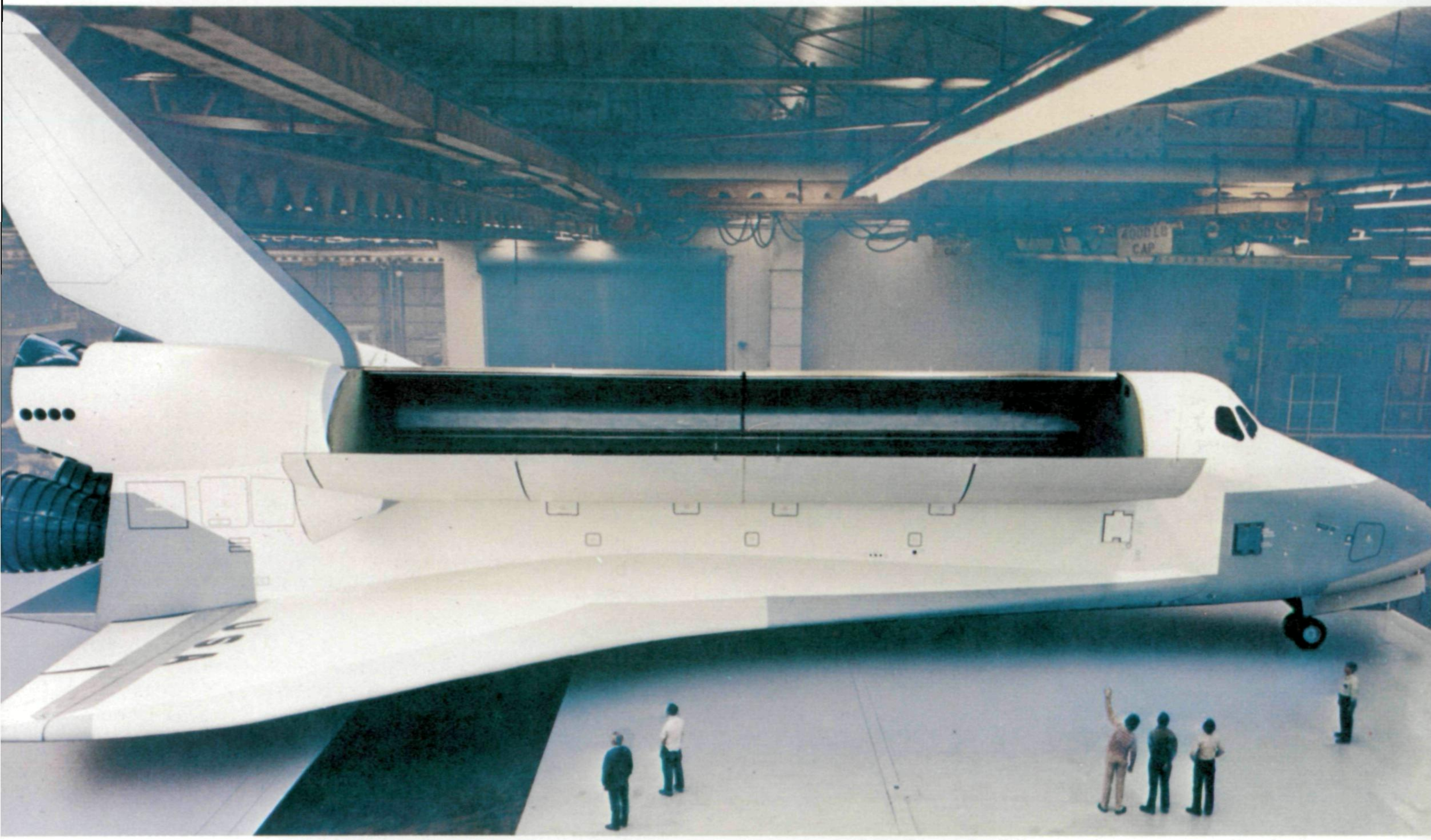
Somewhat later in the Shuttle's future lies the Space Tug, an unmanned reusable stage that will ride in the Shuttle's cargo bay and make it possible for the Shuttle to launch interplanetary probes or put spacecraft into far higher Earth orbits. It will be able to retrieve some satellites.

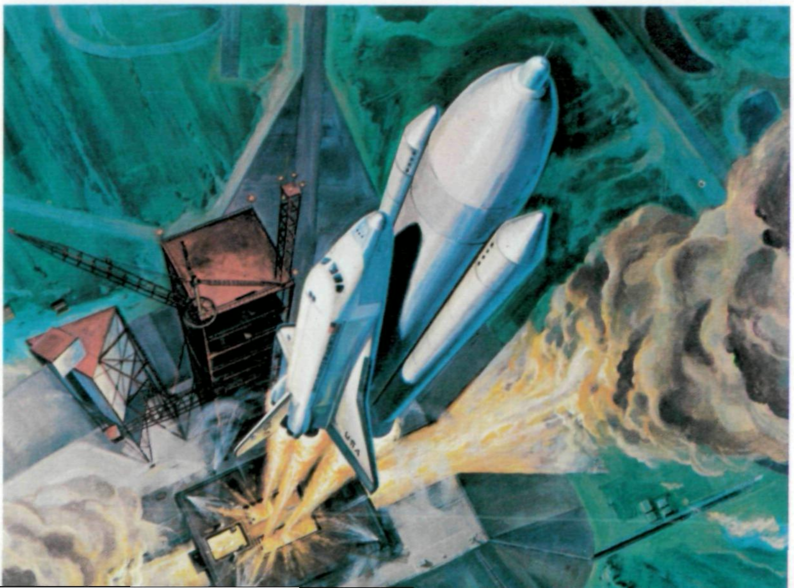
NASA has reached agreement with the Department of Defense for the Air Force to develop the Interim Upper Stage, an early version of the Space Tug. The Interim Upper Stage may not be able to retrieve Earth satellites but may be reusable.

Space Shuttle is keeping to a schedule intended to have it start service in 1980. It has an Orbiter which can retrieve, repair, and, as shown below, launch satellites. It has a Spacelab payload, *(shown in the artist's cutaway at bottom)* in which scientists and engineers can work in shirtsleeves for periods of up to 30 days in Earth orbit. When the mission is complete, the Orbiter returns to Earth and lands like an airplane.



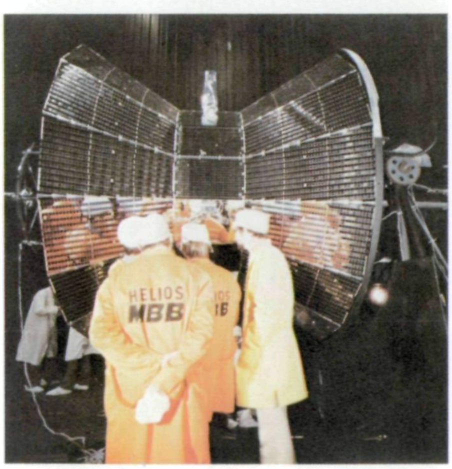
A full-scale mockup of the Space Shuttle Orbiter, with some help from an artist, looked like this when unveiled in 1974 at Downey, California. At launch *(bottom)*, as the artist sees it, the Shuttle lifts off with all engines burning. Soon after launch, the Orbiter will jettison two solid-fuel rockets and, just before going into Earth orbit, cast off the large propellant tank.





International

Cow grazes peacefully near 210-foot tracking antenna which keeps radio contact with interplanetary spacecraft from this site near Madrid, Spain. It is part of the Deep Space Network built and managed by the NASA Jet Propulsion Laboratory.



Of the six scientific satellites NASA launched in 1974 five were built and paid for by other countries, including the West German Helios I. Here Helios undergoes testing in a 25-foot simulation chamber at the Jet Propulsion Laboratory. Helios 1 was launched in December on a mission to study the Sun.

The Apollo-Soyuz efforts that focused on the meeting of American astronauts and Russian cosmonauts in Earth orbit in 1975 have paralleled another significant example of worldwide cooperation in space, Spacelab.

Spacelab will be brought into Earth orbit aboard the Space Shuttle (see page 26) and will remain in the payload bay throughout each mission. In Spacelab's shirt-sleeve environment, scientists and engineers of many countries can carry out experiments requiring 7 to 30 days of supervision in orbit.

The European Space Agency is designing and building Spacelab to its own and NASA specifications, with funds raised from member nations. The organization awarded a $226 million Spacelab development contract to a consortium headed by VFW Fokker/ERNO of the Federal Republic of Germany. The whole project will cost the European nations more than $400 million in today's dollars.

Apollo-Soyuz opens the way to an international, Earth-orbit rescue capability and to future international manned space missions that would eliminate duplications of effort and thereby contribute to economies and progress in space operations. The expense and complexity of certain space activities are far beyond the means of some nations, particularly less-developed ones.

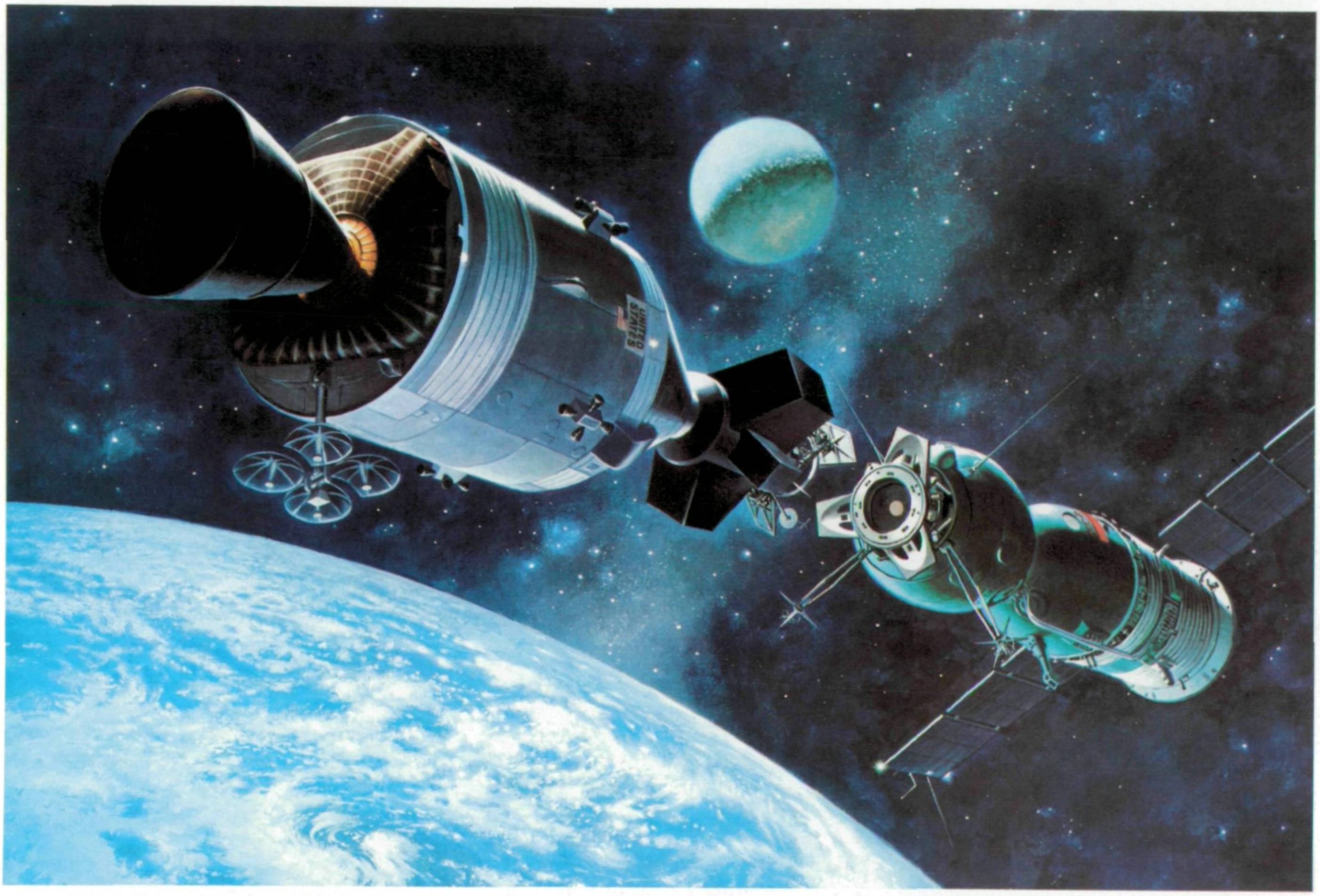
The mutual confidence and trust developed in joint space ventures may be significant not just for what peoples working together may accomplish in orbit but also from what peoples working together may achieve on Earth.

Of the six scientific satellites launched by NASA during 1974, five were built and paid for by other countries. NASA contributed the launching and some of the scientific instruments and both sides are sharing the scientific findings. The five cooperative launches:

- San Marco 4, February 18, with Italy, to measure the density of the upper atmosphere.
- Netherlands Astronomical Satellite, August 30, with the Netherlands, to investigate ultraviolet and X-ray radiation from distant stars and galaxies.
- Ariel 5, October 15, with the United Kingdom, launched from Italy's San Marco platform off the coast of Kenya, to detect and study celestial X-ray sources.
- Intasat, November 15, with Spain, a piggy-back satellite to measure the electron content of the ionosphere.
- Helios 1, December 10, with Germany, a probe to study the solar environment while traveling to within 48 million kilometers (30 million miles) of the Sun.

Investigators from 17 countries and two international organizations have analyzed data from LANDSAT 1 (see page 4) and the Earth Resources Experiment Package on Skylab, NASA's experimental manned space station (see page 33).

Artist's concept shows historic rendezvous of Apollo and Soyuz in Earth orbit.



American and Russian flight crews and controllers for Apollo-Soyuz underwent intensive training together both in the United States and in Russia. Here a group of astronauts and cosmonauts stroll in Red Square.

Small part of great rift valley of Mars as it looks in model based on Mariner photographs. Entire valley is about 4,800 kilometers (3,000 miles) long.

Viking

On or about July 4, 1976, our nation's 200th birthday, an angular, automated envoy of the United States will abandon the path of revolution about Mars and, with rockets' brief flare and parachute, descend to the Martian surface. There, this electronic explorer will scan and scratch for everything it can discover about the planet, especially any evidence of some form of life. The name of this Mars analyst? The Viking lander, a spindly robot with the constitution of a biological and chemical laboratory.

Mars, the most Earth-like of all the planets in the Solar System, is enjoying a revival of great scientific interest thanks to the surprising 1972 findings of Mariner 9 which orbited and mapped the red planet in unprecedented detail. A new Mars was unveiled: an active-type planet, one with major volcanic regions, a huge rift valley running along its equator, numerous features that looked like eroded stream beds and a strange layered terrain in the polar areas. The region around the southern polar cap is extensively eroded as if by glacial action and other pits and slumps resemble ice-formed features on Earth. Based on Mariner 9 results, it is now believed that frozen water deposits exist beneath the Martian poles.

Viking instruments that will be used on the surface and in orbit around Mars will tell us more about the planet, possible origins of life and the possible prospects for our own environment. Since our Earth and the other Solar System planets were formed in the same period, 4.6 billion years ago, anything we can learn about the evolution of one may tell us much about another.

Two Viking spacecraft will help us find out if Mars knows something we don't know.

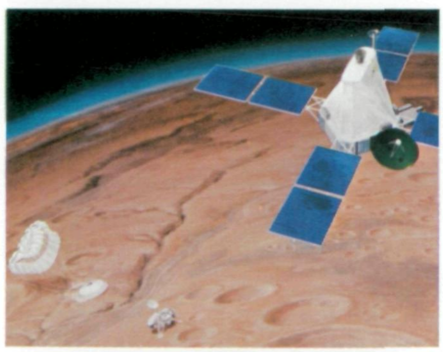
The two Vikings will be launched 10 days apart from NASA's John F. Kennedy Space Center in Florida in August 1975. They will reach Mars about a week apart in late June 1976 and start orbiting the planet.

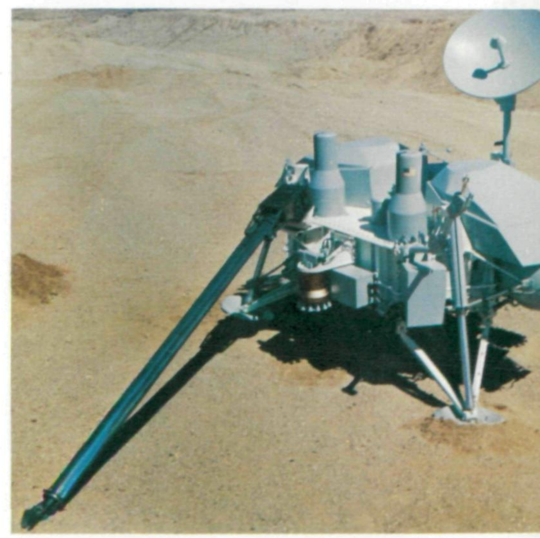
After checking on the suitability of a pre-chosen landing place, each Viking will cut loose its lander portion for descent while the orbiter elements make observations of Mars as they circle the planet. The orbiters will relay to Earth stations data radioed from the landers.

On the way down, the landers will collect information about the Martian atmosphere. Upon putting down, the landers will go to work as automated weather, television, and seismographic stations; biological and chemical laboratories; and robot explorers. For exploration, the landers have retractable claws with magnetometers and pressure sensors that can reach out 10 feet and TV camera eyes which can see in color, black and white, and, when focussed on the same scene, stereo. The cameras can be aimed to scan from the lander's own nearest footpad to an angle 40 degrees above the horizon. The Earth bound experimenters can see through the "eyes" of the lander and manipulate the claw to sample the surface of Mars.

The Viking orbiter, is the responsibility of the Jet Propulsion Laboratory. A far more complex spacecraft, the Viking Lander is the responsibility of the Langley Research Center. Langley must sterilize the lander so that, when searching out Martian life, if any, it does not find organisms delivered there by itself. To avoid that scientific calamity, the lander is being thoroughly cleaned and baked at temperatures no cooler than 114 degrees C (236 degrees F.)

Langley had to design, develop and test equipment for the lander that would work after so severe a baking. It was done. During 1974 a complete lander underwent repeated heat sterilization. This new technology, too, is expected to have applications in health and industry.





Discarded capsule cover and chute rest (top left) on surface of Mars near Viking lander as orbiter passes overhead. Closeup view of lander is above. Viking mission emblem (left) was selected in a national student competition.

Skylab

When the third and last Skylab crew splashed down in the Pacific Ocean in 1974 the astronauts ended the longest and most productive manned space mission in history—84 days, 1 hour and 16 minutes.

Skylab marked the beginning of a new era in space flight, a transition from space exploration to space utilization, from single-purpose spacecraft to multipurpose space stations. From Skylab will come many of the technical and scientific developments which may prove a decisive factor in our struggle with the growing problems of our evolving civilization.

Skylab had several distinct purposes: to enrich our scientific knowledge of the Earth, Sun, stars and cosmic space; to study the effects of weightlessness on living organisms, including man; to develop methods for processing and manufacturing materials in the vacuum and zero gravity of space; and to investigate means of observing and monitoring the Earth's surface to support the needs of man. Most importantly, Skylab sought to evaluate the capabilities, limitations and usefulness of man as a scientist in space.

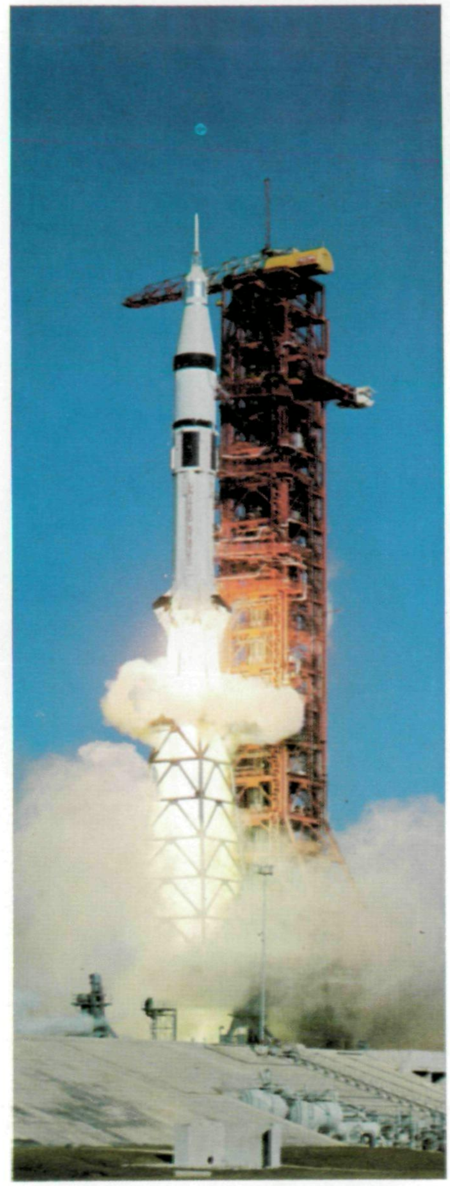
The nation's pioneering space station program proved beyond doubt that man can function effectively for extended periods in space, and clearly demonstrated that he possesses unique advantages over automatic satellites, that he can gather otherwise unavailable scientific data and, if necessary, complete difficult repair and construction jobs that, left unattended, could reduce a mission's effectiveness, even doom it to failure.

In short, Skylab emphasized that in space as well as on Earth there is no substitute for man's adaptability and resourcefulness.

Skylab 4 astronauts Gerald Carr, Edward Gibson and William Pogue toppled space records with abandon, spending more time in space than any other men before, including two record work spans outside their space station of 6½ to 7 hours. Yet, after returning to Earth, they adapted to the terrestrial environment more quickly and proved to be in better physical condition than their predecessors on the Skylab 2 and Skylab 3 missions.* Doctors attributed their good condition to the daily exercises and nutritional supplements that were developed as a result of the two previous flights.

Skylab biomedical findings indicate that there are no medical reasons why man cannot be committed to long duration space missions in Earth orbit or on years' long missions to the other planets of the solar system, provided he has a proper diet and adequately programmed exercise, sleep, work and recreational periods.

Skylab astronauts gave particular attention to studies of the Earth. Using complex Earth sensors, radar and high-resolution photography, they surveyed their world below as



Saturn 1B roars from its launch pad at Kennedy Space Center with the third and last Skylab crew. The three astronauts set records for time in orbit and work outside the spacecraft.

Here's the final photographic look at the now deserted Skylab, shot from the Command Module by a member of the last departing crew. The astronauts, Gerald P. Carr, Edward G. Gibson, and William R. Pogue, splashed down February 8, 1974.

*The Skylab 1 mission was an unmanned launch that put the Skylab space station in orbit. The three Skylab crews were ferried to and from the Skylab by Apollo spacecraft.

Skylab 2 (28 days)—Joseph Kerwin, Charles Conrad and Paul Weitz.

Skylab 3 (59½ days)—Owen Garriott, Alan Bean and Jack Lousma.

never before. Hardly a branch of Earth science was overlooked, from agriculture to forestry, hydrology, geology, geography, meteorology, oceanography and ecology. Among the findings were:

- swirling pools of cool water in the comparatively warm Gulf Stream that may affect the weather.
- indications of underground water in drought-stricken West Africa.
- the effects of strip mining in Illinois, Indiana and Kentucky.
- possible mineral and oil deposits in various locations around the world, including the possibility of placer gold in alluvial streambeds in the Sierra Nevada Mountains.
- startling proof that the mapping of the world's oceans and land masses can be done quickly and accurately from space in a matter of days instead of years using conventional methods.
- that space is the ideal platform for monitoring the world's agricultural resources, marine life, urban development and such scourges as drought, pollution and hurricanes.

Skylab established that orbiting space stations operated by men using sophisticated camera systems and electronic sensors could play a key role in providing information for managing our limited natural resources and protecting our endangered environment.

Even though gravity and atmosphere are necessary for man's normal existence on Earth, they have kept him from perfecting the end products of many manufacturing processes. The special conditions of virtual weightlessness and vacuum intrinsic to orbital flight make it possible to perform operations in materials processing that would be impossible or prohibitively difficult on Earth. Melting and mixing without the contaminating effects of containers, the suppression of convection currents and buoyancy in liquids and molten material, the control of voids, and the ability to use electrostatic and magnetic forces otherwise masked by gravity, open the way to a new knowledge of material properties and processes, and may ultimately lead to the development of valuable new products for use on Earth.

It was expected that zero gravity and vacuum would have a favorable effect on the manufacture of metal alloys, composite materials, crystals and vaccines—and Skylab results did not disappoint.

Experiments show that in the absence of gravity various metal alloys can be strengthened by a uniform distribution of fibers in much the same manner that concrete is reinforced by the addition of steel rods. This is difficult to achieve on Earth because the fibers tend to "float" out of the molten metal when it is compressed to squeeze out voids or empty pockets. In zero gravity, the fibers stay put. Metals of this type exhibit high-strength/low-weight characteristics, and should be a significant contribution to the structural material field.

Another advantage of weightlessness is the capacity to suspend liquids or molten solids without using a container which can introduce undesirable stresses and contamination during solidification. This could be of importance in the production of high quality crystals and semiconductors used in solid state electronics (especially computers), lasers and electro-optical devices. Skylab experimenters demonstrated the production of crystals in space of a size and purity impossible to attain on Earth. Furthermore, it is possible that crystals produced in space would be ready for immediate use in electronic devices without having to undergo the normal, tedious cutting and polishing operations now required.

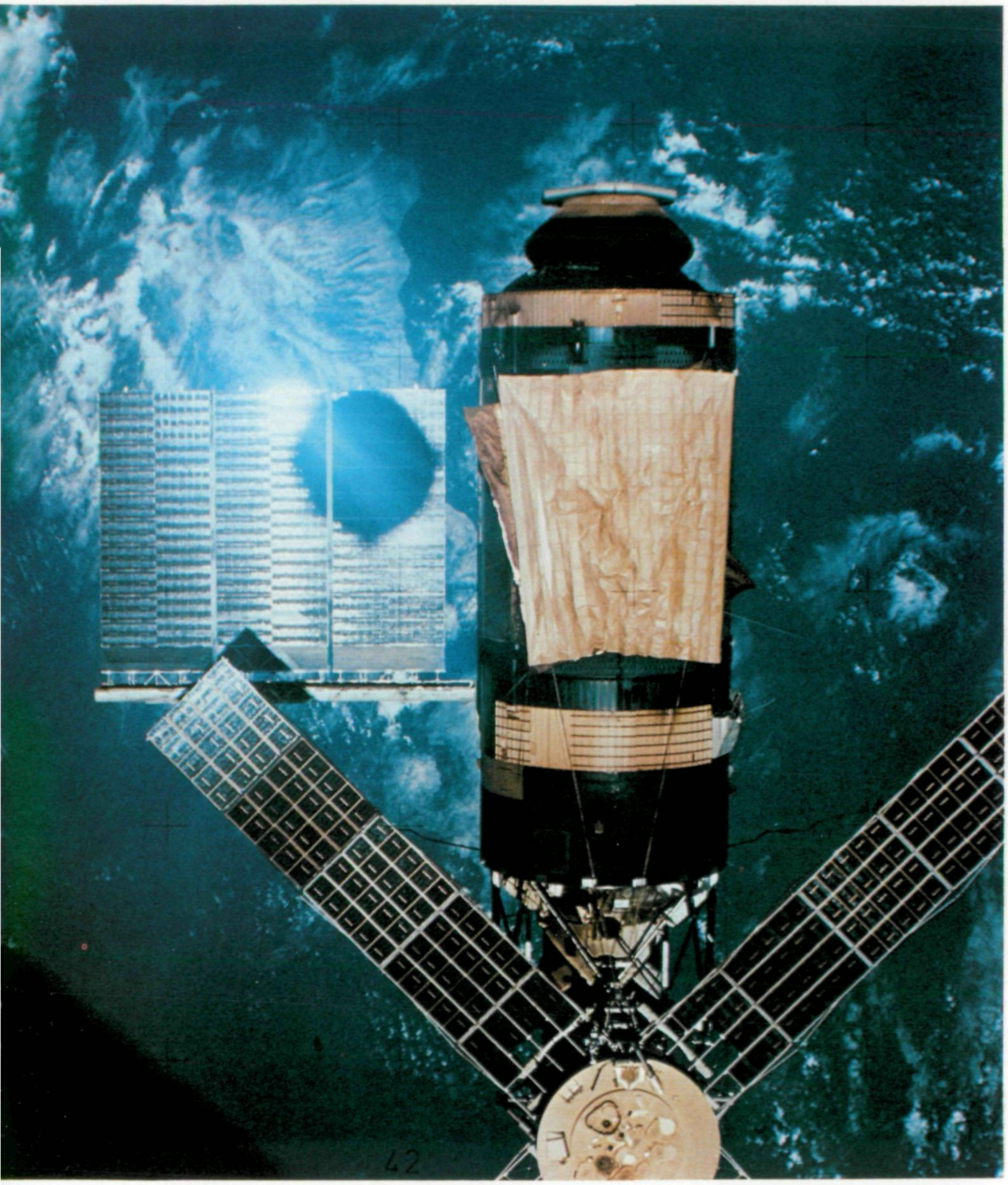
Skylab studies of the Sun were the most extensive and rewarding in the history of man. Since the Sun is the source of all life and energy on Earth, it is imperative that we understand its effects and processes.

For example, the Sun provides the energy that drives the atmosphere and is responsible for the weather. Variations in local solar input give rise to seasons. "Solar energy" lifts water vapor from the oceans and lets it rain down on land and in reservoirs for hydroelectric power plants. Oil and coal contain solar energy stored by life forms millions of years ago.

Ultraviolet and X-ray emissions from the Sun are responsible for our ionosphere which is essential to radio communications. Another vital product of solar ultraviolet radiation is the Earth's ozone layer in the upper atmosphere. Ozone, once formed by the interaction of molecular oxygen with the ultraviolet radiation itself, absorbs ultraviolet, preventing most of it from reaching the surface. With-

Skylab looked like this from above. The round shadow is the departing Command Module on its last "fly around" of the ghost ship.

In-flight photo shows Skylab astronaut positioned before the instrument console from which he controlled operations of the space station's solar physics telescopes.

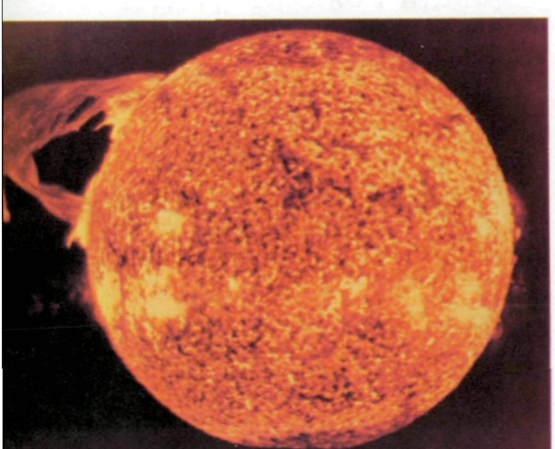


Circular curtain that attached to ceiling, a push-button shower head, and a suction hose to remove water droplets helped make taking a shower possible in weightlessness of Skylab.

out ozone shielding, life on Earth would be impossible.

Solar flares, the sudden release of immense energy and material from the Sun's surface, produce massive disturbances in the solar wind—a sheath of hot, electrified gas particles racing outward from the Sun that bathes the planets in radiation—causing magnetic storms on Earth that disrupt communications, knock out commercial power systems, interfere with sensitive instrumentation and create the brilliant auroral displays in the far northern and southern latitudes. These Sun-generated storms appear to affect global weather patterns as well, and may produce climatic changes whose consequences can be both productive and catastrophic.

Flare on the Sun, photographed by the last Skylab crew, arcs more than 367,000 miles across the surface.



The Sun serves as a laboratory for understanding plasmas or high-temperature gases that conduct electricity and interact with magnetic fields, holding forth the promise of new energy sources here on Earth such as nuclear fusion—the process of the stars—which would give man an inexhaustible supply of cheap, non-polluting energy.

The Sun is also our bridge to the study of other stars. The more we know about the Sun, the only star close enough to study in detail, the more we can use it as a reference point for understanding what is happening on other stars. Conversely, since other stars are in different stages of evolution, they picture the past and future of our Sun.

Telescopic images of the Sun in the visible, ultraviolet and X-ray portions of the spectrum taken by the Skylab astronauts, which cannot be obtained from the ground because of the Earth's atmosphere, confirmed many previous theories and disclosed much that was new. For example, they strengthened evidence that the solar corona—the active, gaseous envelope surrounding the Sun—is more dynamic, complex and changeable than previously thought. And that much of the solar wind may escape into space through mysterious holes in the corona that are much cooler and more rarified than the rest of the corona.

Skylab data indicated that prominences—condensed arches of hot, luminous gases rising from the Sun—erupt more frequently than expected. For the first time, the birth, growth and subsidence of a solar flare was recorded. It was discovered also that active regions on the Sun sometimes signal impending flare activity by becoming brighter in different parts of the region. This factor may eventually give us the capability to predict the onset of flares hours in advance.

The reservoir of information about the Sun accumulated during the Skylab missions will require years of intensive study. Like a pistol shot that can trigger an avalanche, each new discovery will widen our understanding of the most important of our celestial neighbors.

However disappointing to observers on Earth, Comet Kohoutek gave the Skylab astronauts a unique opportunity. The comet, discovered far out in space in March 1973, was sighted by the astronauts on December 13, 1973. They promptly focussed their instruments on it, making daily observations as it swept toward the Sun and then sped away. (NASA also collected data on Kohoutek via the unmanned spacecraft Mariner 10, the Orbiting Astronomical Observatory, sounding rockets, high altitude balloons, aircraft, and ground observatories.)

The result was a significant contribution to cometary physics. For example, observations on the amount of hydrogen carried from the nucleus of Kohoutek at separate stages of its

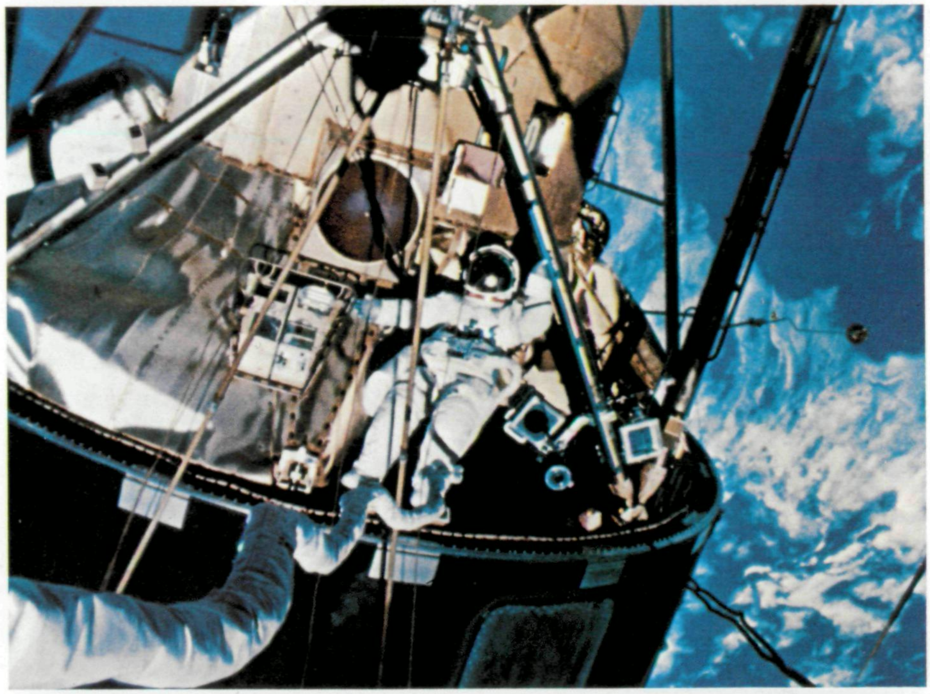
sweep clearly showed the development and decline of its huge hydrogen halo. Scientists concluded that the comet ejected more material before than after perihelion (closest approach to the Sun). This suggested that Kohoutek had never been close to the Sun before and, therefore, was on its first visit to our part of the solar system.

Today, Skylab is a ghost ship, destined to circle the Earth dark and vacant for as long as 10 years. In time, it will drift down into the denser part of the atmosphere. Eventually, atmospheric friction will heat and cause it to break apart, falling to Earth like a meteor shower in a fiery finale to a brilliant career.

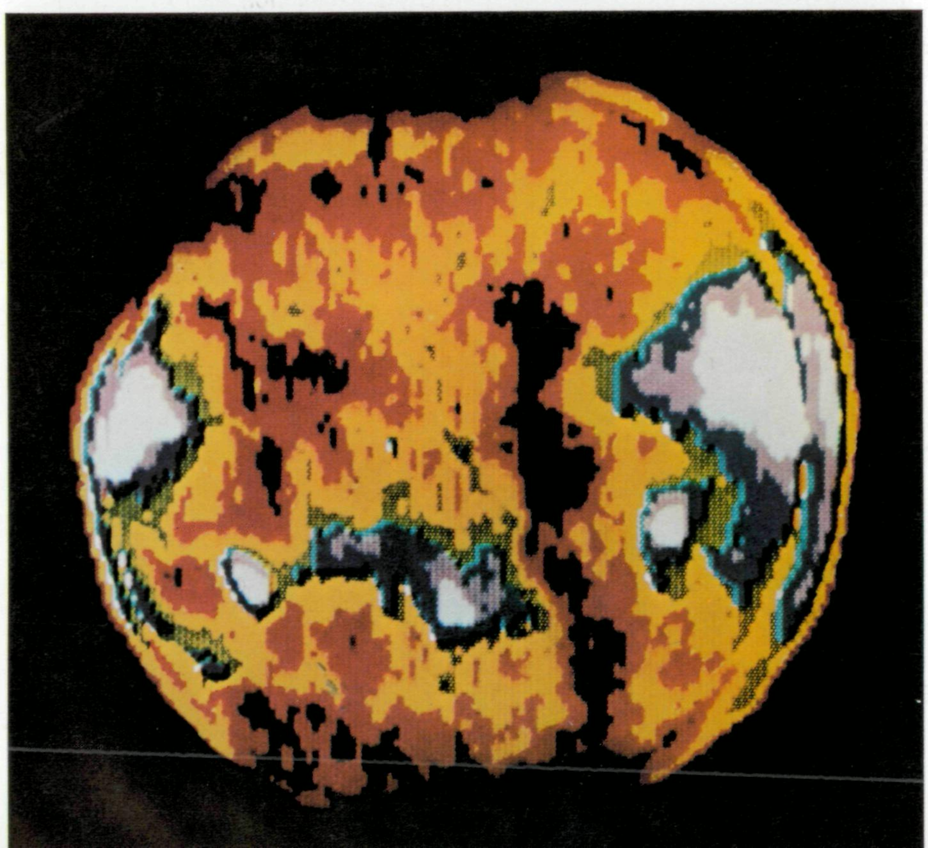
Skylab, in all its aspects, has demonstrated that this nation is capable of conducting broader and more useful beneficial activities in space that directly relate to our own planet Earth. It has served as a true orbiting research facility enabling our astronauts to carry out a wide spectrum of scientific, engineering and biomedical studies.

Results of Skylab experiments, besides enriching our knowledge in technology and science, will undoubtedly influence many other space projects to be developed by the United States and others during forthcoming years, A new generation of manned orbiting flights, again expanding our capabilities in space and the utility of space flight for man on Earth, will begin with the Space Shuttle Program around the end of the 1970's. The Shuttle Program, too, will profit decisively from Skylab, our first station in space.

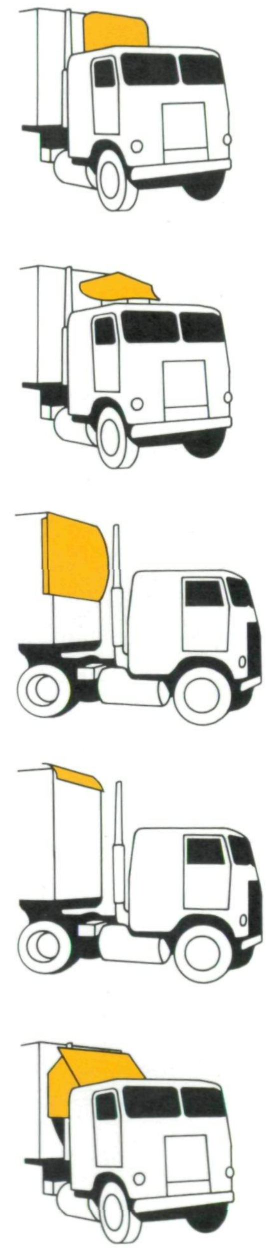
Shortly before the end of the Skylab mission, Scientist-Astronaut Edward G. Gibson climbed out of the hatchway to begin the crew's final extra-vehicular activity. From above the obscuring atmosphere of the Earth, the astronauts got a unique opportunity to observe Comet Kohoutek.



Below: Orbiting spectroheliograph produced portrait of the Sun. White represents greatest heat and color code scales down through yellow, red and blue. Dark areas are coronal holes investigated by Skylab instruments.



Energy



At 88 kilometers (55 miles) an hour, devices top and bottom did best in reducing air drag on this trucking rig.

In cooperation with the Energy Research and Development Administration, NASA is applying aerospace technology to help meet critical national needs for both conserving energy and developing new, renewable, economically practicable, and environmentally acceptable energy sources.

In one program, NASA is improving and demonstrating solar collector systems that absorb heat from the Sun to heat and cool buildings. NASA's work on thermal coatings for spacecraft is being applied to improve the efficiency of solar collectors. An experimental house at the NASA Marshall Space Flight Center will ultimately derive 85 percent of its heating and cooling from a solar collector system. At NASA's Langley Research Center, a new 53,000-square-foot office building is to derive as much as 90 percent of its heating and 50 percent of its cooling from a solar collector system that is part of an experimental, large-scale test facility.

Another NASA and Energy Research and Development Administration project is applying aerospace advances to windmill design. Windmills have provided some electricity in many countries for more than half a century. The current project is aimed at improving the performance, operation, and economics of wind-driven electricity generating systems for future commercial use. Construction and test operation of a 100-kilowatt wind generator (windmill) is under the direction of NASA's Lewis Research Center.

Solar cells arrays, which power nearly all NASA spacecraft, can convert sunlight directly into electricity, even on cloudy days. They are finding use on Earth in remote areas for special tasks where their high cost ($20 to $50 per watt) is not limiting; for example, automatic weather stations and navigational buoys.

NASA is conducting a program to reduce the cost and increase the efficiency of solar cells. It has made promising progress in growth of high quality single-crystal silicon ribbons for application to mass-produced low cost solar cells. The technique can replace the present costly process of sawing thin wafers from large cylinders of single-crystal silicon.

NASA has conducted tests for the Department of Transportation of add-on devices which may reduce air drag on trucks. Air drag absorbs a significan part of the horsepower of a vehicle, particularly at high speeds. The trucks were tested at the NASA Flight Research Center. Aerodynamic tests with automobiles have been conducted by NASA's Jet Propulsion Laboratory.

The Jet Propulsion Laboratory is testing the use of hydrogen in internal combustion engines to save fuel and reduce exhaust pollution. Hydrogen injected into the gasoline-air mixture makes it burn at leaner mixtures. In addition, gas turbines for automobiles are being tested for the Environmental Protection Agency at NASA's Lewis Research Center.

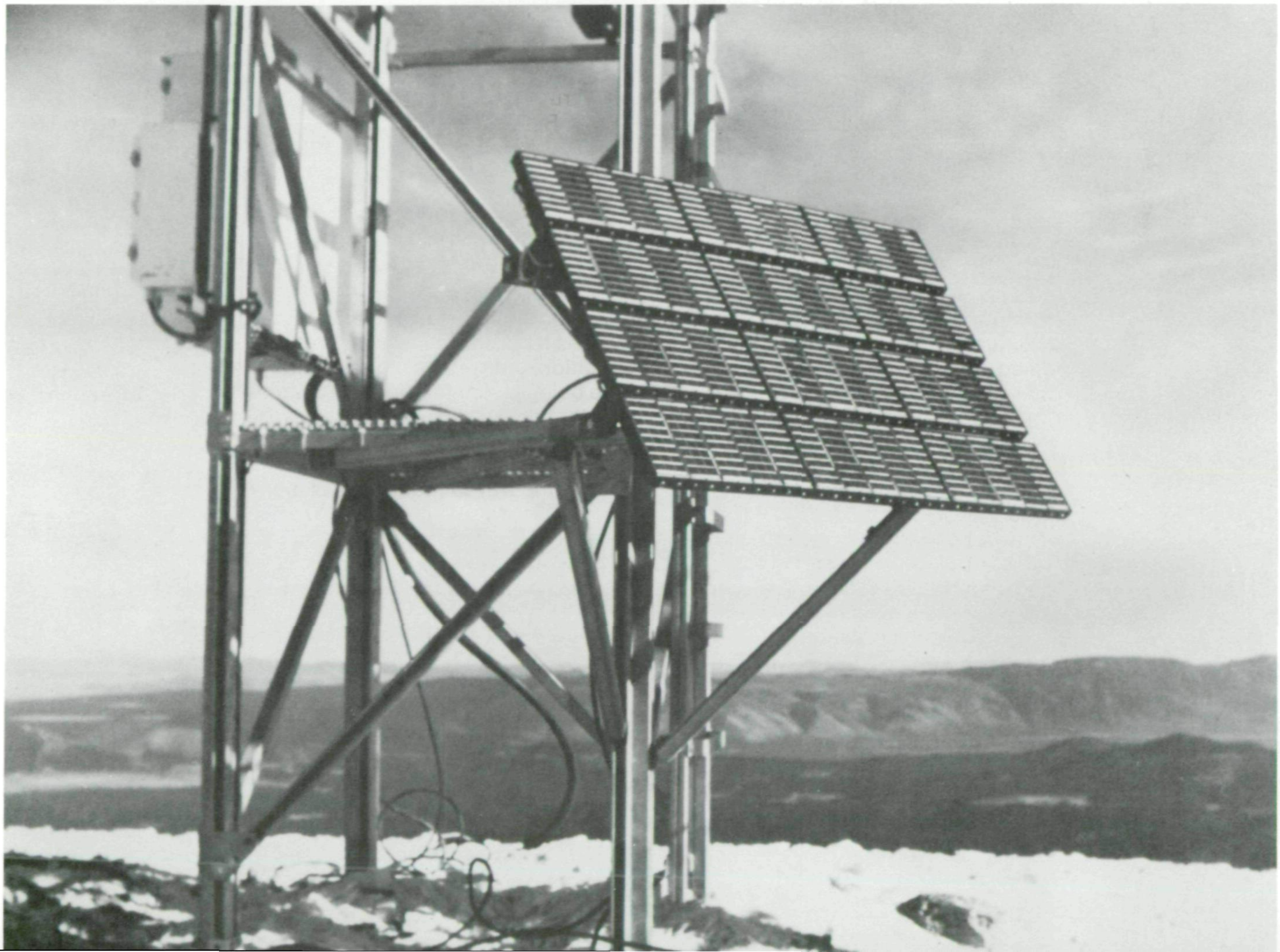
Work on Integrated Utility Systems points the way to reductions of more than 40 percent in fuel used for apartments, office buildings, shopping centers, and schools, plus substantial decreases in sewage. Waste heat

from electric-power generation is used for space and water heating, air conditioning, and recycling of liquid waste. In addition, on-site incineration of solid waste produces additional heat energy while reducing refuse to small amounts of noncombustible ash. The integrated system is an application in part of technical approaches and design philosophies developed from NASA studies for future large space stations.

Other energy-related NASA research and development programs involve energy transmission and storage, energy and environmental conservation, and the search for energy resources.

Model of 100-kilowatt windmill to be tested in Ohio. Rotor blades span 47.5 meters (125 feet) from tip to tip.

Remote weather station atop California mountain is powered by solar cell arrays encapsulated in plastic to protect against harsh weather.



Working Together

The preamble to the Act of Congress creating the National Aeronautics and Space Administration put it plainly: "It is the policy of the United States that activities in space should be devoted to peaceful purposes for the benefit of all mankind." In the years since, the agency has hewed to that clear line and the far-reaching results are so varied they are hard to summarize:

Satellite systems, growing ever more reliable, speed communications around the globe, collect information about the Earth, monitor its weather, spot resources of pollution, and help find deposits of fuel. Men have explored the Moon and unmanned spacecraft have had closeup looks at Mercury, Venus, Mars, and Jupiter, telling science more about our near neighbors in space than centuries of study through telescopes shrouded by the Earth's atmosphere. Aeronautical research has strengthened American leadership in aviation.

Technology resulting from these efforts has contributed to electronics, medicine, agriculture, indeed to nearly every human endeavor. By sharing that technology and our scientific discoveries with the world, as well as helping other countries explore space, the United States has fostered international goodwill and cooperation.

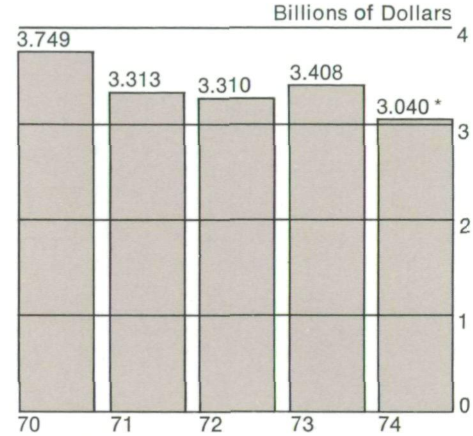
It all began in 1958 with passage of Public Law 85-568, the National Aeronautics and Space Act, on July 29. NASA actually took form on October 1, 1958, by absorbing the 43-year-old National Advisory Committee for Aeronautics (NACA), which besides a headquarters in Washington had five field centers: Ames Aeronautical Laboratory (now Ames Research Center), Mountain View, California; High Speed Flight Station (now Flight Research Center), Edwards, California; Langley Aeronautical Laboratory (now Langley Research Center), Hampton, Virginia; Lewis Flight Propulsion Laboratory (now Lewis Research Center), Cleveland, Ohio; and the Pilotless Aircraft Research Center (now Wallops Flight Center), Wallops Island, Virginia. Also acquired was the Navy's Project Vanguard.

NASA then assumed direction of the Jet Propulsion Laboratory of the California Institute of Technology, Pasadena, California, and took over the Development Operations Division of the Army Ballistics Missile Agency, which became the George C. Marshall Space Flight Center, Huntsville, Alabama, and the Army Ballistics Missile Agency launch operations at Cape Canaveral, Florida, which was developed into the John F. Kennedy Space Center.

Later on, NASA established Goddard Space Flight Center, Greenbelt, Maryland; Manned Spacecraft Center (now Lyndon B. Johnson Space Center), Houston, Texas; and the Mississippi Test Facility (now National Space Technology Laboratories), Bay St. Louis, Mississippi. The Electronics Research Center at Cambridge, Massachusetts, which NASA founded, has been shifted to the Department of Transportation.

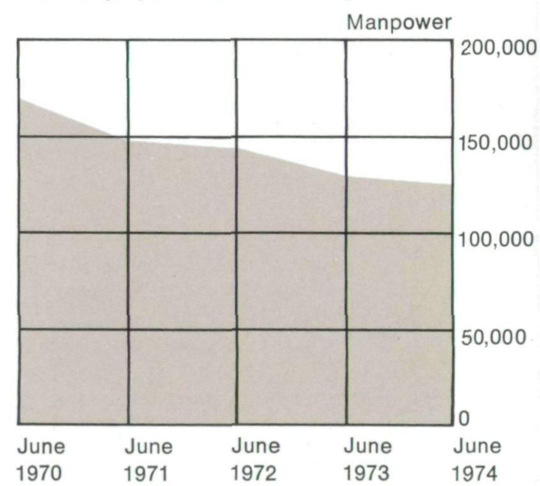
The agency employs nearly 25,000 persons who work with industry, educational institutions, and other government agencies both in the United States and abroad on its assigned tasks in aerospace science and technology.

Appropriations By Fiscal Years



* Includes $37.6 million supplement

Total Employment On NASA Programs



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Financial Summary (In Millions of Dollars)

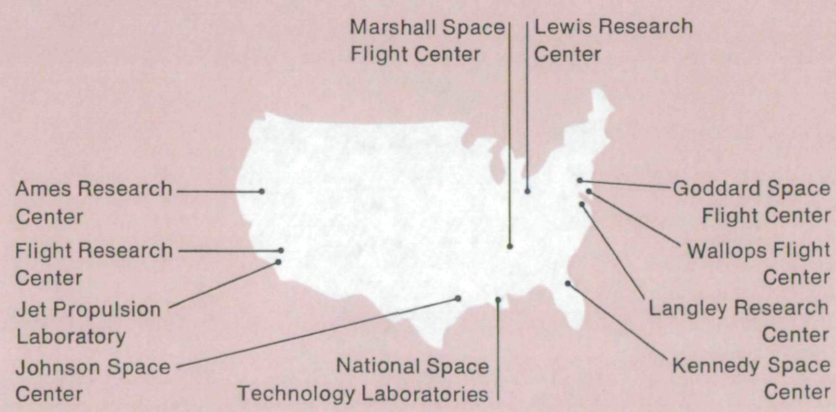
Fiscal Year	Total Appropriations	Total Obligations	Total Outlays
1959	330.9	298.7	145.5
1960	523.6	486.9	401.0
1961	966.7	908.3	744.3
1962	1,825.3	1,691.7	1,257.0
1963	3,674.1	3,448.4	2,552.4
1964	5,100.0	4,864.8	4,171.0
1965	5,250.0	5,500.7	5,092.9
1966	5,175.0	5,350.5	5,933.0
1967	4,968.0	5,011.7	5,425.7
1968	4,588.9	4,520.4	4,723.7
1969	3,995.3	4,045.2	4,251.7
1970	3,749.2	3,858.9	3,753.1
1971	3,312.6	3,324.0	3,381.9
1972	3,310.1	3,228.6	3,422.9
1973	3,407.7	3,154.0	3,315.2
1974	3,039.7	3,122.4	3,256.2

Personnel Summary *On Board at End of Fiscal Year* [a]

Installation	FY 1974	FY 1973	FY 1972	FY 1971	FY 1970
NASA Headquarters	1,734	1,747	1,755	1,895	2,187
Ames Research Center	1,776	1,740	1,844	1,968	2,033
Electronics Research Center	—	—	—	—	592[b]
Flight Research Center	531	509	539	579	583
Goddard Space Flight Center	3,936	3,852	4,178	4,459	4,487
Kennedy Space Center	2,408	2,516	2,568	2,704	2,895
Langley Research Center	3,504	3,389	3,592	3,830	3,970
Lewis Research Center	3,172	3,368	3,866	4,083	4,240
Johnson Space Center	3,886	3,896	3,935	4,298	4,539
Marshall Space Flight Center	4,575	5,287	5,555	6,060	6,325
Space Nuclear Systems Office	—	—	45	89	103
NASA Pasadena Office	39	39	40	44	72
Wallops Flight Center	447	434	465	497	522
NASA Total	26,007	26,777	28,382	30,506	32,548

[a] Includes both permanent and temporary employees.
[b] ERC was closed effective midnight June 30, 1970.

NASA Field Installations



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